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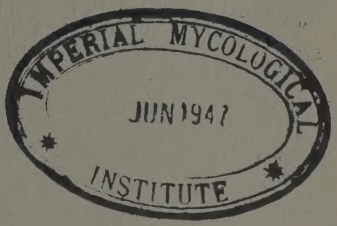

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MATHEMATICS

ON A REMARKABLE CLASS OF HERMITIAN OPERATORS

By M. KREIN

(Communicated by S. N. Bernstein, Member of the Academy, 20. XI. 1943)

The theory developed in the notes ([1], [2]) enables us to discover a new remarkable class of Hermitian operators.

1. A simple Hermitian operator A with deficiency indices equal to one will be called an integral operator, if there exists a scale u (called integral scale) such that to every vector $f \in \mathfrak{H}$ corresponds an integral function $f_u(z)$.

If A is an integral Hermitian operator, then in virtue of Theorem 8([2]) it is regular, and thus every its self-adjoint extension $\widetilde{A}$ has for its inverse operator a completely continuous operator. If u is chosen to be an integral scale, one may assert on the basis of Theorem 3([2]) that an unbounded non-decreasing function $\sigma(\lambda) = \sigma(\lambda - 0)$ $[-\infty < \lambda < \infty, \sigma(-\infty) = 0]$ belongs to V_u if and only if for any two elements $g, f \in \mathfrak{H}$ there holds the relation:

$$(g, f) = \int_{-\infty}^{\infty} g_u(t)\overline{f_u(t)}\, d\sigma(t)$$

The space $\mathfrak{H}_u \subset L^{(2)}_\sigma$ will coincide with $L^{(2)}_\sigma$ if and only if the function $\sigma \in V_u$ is canonic.

2. The scale u of an Hermitian operator A is called real, if from $f(z) \in \mathfrak{H}_u$ follows that also

$$\overline{f}(z) \in \mathfrak{H}_u \qquad [\overline{f}(z) = \overline{f(\bar{z})}].$$

Theorem 1. *For every integral Hermitian operator A there always exist a real integral scale. It is determined up to a scalar factor.*

In the following assertions we assume without mentioning it that A is an integral operator, and u, a real integral scale.

Put

$$D(z) = \sup_{f \in \mathfrak{H}} \frac{|f_u(z)|^2}{(f, f)} \tag{1}$$

Theorem 2. *The function $D(z)$ possesses the following properties:*

1) *The function $D(x+iy)$ is an even function of y, monotonously increasing with $|y|$.*

2) *The following inequalities hold*

$$(u, u)e^{2h|y|} \leqslant D(x+iy) \leqslant e^{2h|y|+o(r)} \quad (r=\sqrt{x^2+y^2}) \tag{2}$$

where $h \geqslant 0$.

3) $\log D(z)$ *is a continuous subharmonic function possessing in the upper half-plane a harmonic majorant, namely*

$$\log D(x+iy) \leqslant 2hy + \frac{y}{\pi}\int_{-\infty}^{\infty} \frac{\log D(t)}{(t-x)^2+y^2}\,dt < \infty \quad (y>0) \tag{3}$$

The number h uniquely corresponding to the integral operator A will be called the type of the operator A. Since in virtue of (1) we have

$$|f_u(z)| \leqslant (f, f)^{1/2} D^{1/2}(z),$$

it may be concluded from Theorem 2 that every function $f_u(z) \in \mathfrak{H}_u$ possesses certain properties as regards the increase of its modulus; from this may be deduced a series of consequences relative to the situation and frequency of its zeros, which we refrain, however, from doing on account of the space available.

It may be remarked moreover that in virtue of inequality (2) and Theorem 9 ([2]) $\mathfrak{H}_u$ contains the totality L_h of all integral functions $f(z)$ satisfying the two conditions:

$$\overline{\lim_{z\to\infty}} \frac{\log|f(z)|}{|z|} \leqslant h, \qquad \sup_{-\infty<x<\infty} |f(x)| < \infty$$

In particular, $\mathfrak{H}_u$ contains all functions $v(z)$ of the form $v(z)=Ce^{i\alpha z}$ where $-h \leqslant \alpha \leqslant h$. It may be shown that the element $v \in \mathfrak{H}$ will be an integral scale of the operator A if and only if $v_u(z)=Ce^{i\alpha z}$ $(C \neq 0;\ -h \leqslant \alpha \leqslant h)$.

Under 4b) will be constructed an example of an operator A, for which L_h is dense in $\mathfrak{H}_u$.

3. Let $\{\varphi_k\}_1^\infty$ be a certain complete orthonormed system of elements in $\mathfrak{H}$; put for brevity

$$\varphi_k(z) = \varphi_{ku}(z) \qquad (k=1, 2, \ldots)$$

then

$$D(z) = \sum_1^\infty |\varphi_k(z)|^2$$

We introduce also functions

$$\psi_k(z) = \int_{-\infty}^{\infty} \frac{\varphi_k(z)-\varphi_k(t)}{z-t}\,d\sigma(t) \qquad (\sigma \in V_u;\ k=1, 2, \ldots) \tag{4}$$

«adjoint» to $\varphi_k(z)$ $(k=1, 2, \ldots)$ [cf. p. 5([1])] *.

Since u is a real scale, we may assume without loss of generality that the functions $\varphi_k(z)$ $(k=1, 2, \ldots)$ are real for real z; then the same property will be enjoyed also by the functions $\psi_k(z)$ $(k=1, 2, \ldots)$.

Putting then [cf. formulae (9)([1])] **

---

* It is easily seen that the integrals (4) do not depend. on the choice of the function $\sigma \in V_u$ [cf. p. 5 ([1])].

** The series (6) converge absolutely and uniformly in every finite domain in virtue of the fact that the series $\Sigma|\varphi_k(z)|^2$ and $\Sigma|\psi_k(z)|^2$ [cf. Theorem 7 ([2])] possess this property.

$$\left.\begin{aligned} q_0(z) &= 1 - z\sum_1^\infty \varphi_k(z)\psi_k(0, & q_1(z) &= -z\sum_1^\infty \varphi_k(z)\varphi_k(0), \\ p_0(z) &= z\sum_1^\infty \psi_k(0)\psi_k(z), & p_1(z) &= 1 + z\sum_1^\infty \varphi_k(0)\psi_k(z) \end{aligned}\right\} \tag{5}$$

we shall have the identities

$$\left.\begin{aligned} q_0(z)q_1(\zeta) - q_1(z)q_0(\zeta) &= (z-\zeta)\sum_1^\infty \varphi_k(z)\varphi_k(\zeta) \\ p_0(z)p_1(\zeta) - p_1(z)p_0(\zeta) &= (z-\zeta)\sum_1^\infty \psi_k(z)\psi_k(\zeta) \\ q_0(z)p_1(\zeta) - q_1(z)p_0(\zeta) &= 1 + (z-\zeta)\sum_1^\infty \varphi_k(z)\psi_k(\zeta) \end{aligned}\right\} \tag{6}$$

According to Theorem 7(1) the relation

$$\frac{p_0(z)+\tau(z)\,p_1(z)}{q_0(z)+\tau(z)\,q_1(z)} = \int_{-\infty}^{\infty} \frac{d\sigma(t)}{t-z} \qquad (\mathrm{I}z > 0)$$

establishes a one-to-one correspondence between the functions $\sigma \in V_u$ and the functions $\tau(z)$ holomorphic in the upper half-plane and possessing there a non-negative imaginary part, if only we exclude the function $\sigma_\infty \in V_u$ corresponding to $\tau(z) = \infty$; herewith the function $\sigma \in V_u$ will be canonic if and only if the function $\tau(z)$ reduces to a real constant (finite or infinite).

Hence, using the identities (6), we easily deduce that the points of increase (leaps) of the canonic function $\sigma_\xi(t)$ discontinuous at the point ξ, coincide with the roots of the integral transcendental equation $q_0(z)q_1(\xi) - q_1(z)q_0(\xi) = 0$ or, which is the same, of the equation

$$(z-\xi)\sum_1^\infty \varphi_k(\xi)\varphi_k(z) = 0 \tag{7}$$

All these roots are real and simple.

Besides, we find

$$\sigma_\xi(\xi+0) - \sigma_\xi(\xi-0) = \frac{p_0(\xi)q_1(\xi) - p_1(\xi)q_0(\xi)}{q_0'(\xi)q_1(\xi) - q_1'(\xi)q_0(\xi)} = \Big[\sum_1^\infty \varphi_k^2(\xi)\Big]^{-1} = D^{-1}(\xi)$$

Consequently, if

$$\ldots < \xi_{-2} < \xi_{-1} < \xi_0 = \xi < \xi_1 < \xi_2 < \ldots$$

are the roots of the equation (7), then, putting

$$\rho(\xi) = D^{-1}(\xi) \qquad (-\infty < \xi < \infty)$$

we arrive at the following formula for $\sigma_\xi(t)$

$$\sigma_\xi(t) = \sum_{\xi_j < t} \rho(\xi_j) \qquad (-\infty < \xi < \infty)$$

The following theorem is an analogue and, if we please, a generalization of the known «Tschebysheff's inequality» relating to the problem of moments ([3], [4]).

Theorem 3. *For every function $\sigma \in V_u$ hold the estimations*

$$\sigma(\xi+0) \leqslant \sum_{\xi_j \leqslant \xi} \rho(\xi_j), \qquad \sigma(\xi-0) \geqslant \sum_{\xi_j < \xi} \rho(\xi_j)$$

whereby the sign of equality is possible in any of these relations if and only if $\sigma \in V_u$ coincides with the function σ_ξ.

Applying Theorem 2 we may show that the left-hand side of the equation (7) [which we denote by $Q_\xi(z)$] satisfies the condition

$$\overline{\lim_{z\to\infty}} \frac{\log|Q_\xi(z)|}{|z|} = h, \qquad \lim_{r\to\infty} \frac{\log|Q_\xi(re^{i\varphi})}{r} = h|\sin\varphi| \quad (e^{i\varphi} \neq \pm 1) \tag{8}$$

and that in the second of these equalities the convergence to the limit is uniform on every closed set of values of φ for which $e^{i\varphi} \neq \pm 1$.

Denoting, further, by $n(r)$ the number of roots ξ_j situated within the interval $(-r, r)$, we may show that *

$$\frac{2h}{\pi} - \frac{1}{2R}\log R + O(1) \leqslant \frac{1}{R}\int_0^R \frac{n(r)}{r}dr \leqslant \frac{2h}{\pi} + O(1), \qquad n(R) = O(R) \qquad (R \to \infty)$$

4. We give some examples of integral Hermitian operators.

a) Let for a sequence of real numbers s_k the problem of moments

$$s_k = \int_{-\infty}^{\infty} t^k\, d\sigma(t) \qquad (k = 0, 1, 2, \ldots) \tag{9}$$

have an infinity of different non-decreasing solutions $\sigma(t)$ [$\sigma(-\infty) = 0$, $\sigma(t-0) = \sigma(t)$]. Denote by L the set of all possible polynomials in t with complex coefficients. We define the scalar product of two polynomials $P(t) = \sum \alpha_k t^k$ and $Q(t) = \sum \beta_l t^l$ by the formula $(P, Q) = \sum s_{k+l}\alpha_k\overline{\beta}_l$.

In L we define the operator A', putting for any polynomial $P(t)$ $A'P = tP(t)$. Form the closure of the incomplete Hilbert space L' up to a complete $\mathfrak{H}$ and then extend the operator A' to a closed Hermitian operator A in $\mathfrak{H}$. Then the operator A will be an integral Hermitian operator of type zero ($h = 0$) **. The integral scale u of the operator A will be the polynomial $\equiv 1$. For this choice of the scale the set V_u will coincide with the set of all normed solutions of the problem (9). All most important results relating to the problem of moments ([5]) will be simple consequences of our general theory.

* For $h = 0$ the first of the equalities (8) implies, as is known, $n(R)/R \to 0$ as $R \to \infty$.

** The equality $h = 0$ for this operator requires a separate proof which is easily given.

b) Let $F(x)$ $(-2h \leqslant x \leqslant 2h)$ be a continuous not uniquely continuable positive definite function, *i. e.* a function admitting an infinity of essentially different representations [cf. (6)],

$$F(x) = \int_{-\infty}^{\infty} e^{ixt}\, d\sigma(t) \quad (-2h \leqslant x \leqslant 2h) \tag{10}$$

where $\sigma(t)$ $(-\infty < t < \infty)$ is a bounded non-decreasing function. Denote by L the totality of integral functions $\varphi(t)$ of the form

$$\varphi(t) = \int_{-h}^{h} e^{itx}\, d\alpha(x) \quad (-\infty < t < \infty) \tag{11}$$

where $\alpha(x)$ $(-h \leqslant x \leqslant h)$ is a complex valued function of bounded variation.

Define in L the scalar product by putting for $\varphi \in L$ and $\psi \in L$

$$(\varphi, \psi) = \int_{-h}^{h} \int_{-h}^{h} F(x-y)\, d\alpha(x)\, \overline{d\beta(y)}$$

where $\alpha(x)$ and $\beta(x)$ $(-h \leqslant x \leqslant h)$ are functions of bounded variation, involved in the representation (11) for φ and ψ, respectively.

Denote by $\mathfrak{H}$ the closure of L up to a complete Hilbert space and consider in $\mathfrak{H}$ the closed Hermitian operator A obtained as the closure of the operator A' defined by the relation $A'\varphi = t\varphi$ on all those $\varphi \in L$ for which $t\varphi \in L$.

We prove that A is an integral Hermitian operator of the type h. The integral scale for A will be any element $\varphi \in L$ of the form $\varphi(t) = Ce^{i\alpha t}$ $(C \neq 0, -h \leqslant \alpha \leqslant h)$. The scale will be real, if $\alpha = 0$. For $C = 1$ the set V_u will coincide with the set of bounded non-decreasing functions involved in the representation (10) of the function $F(x)$ [cf. also (7)].

Hence we may obtain a series of essential addenda to the author's investigations (6) on the problem of continuation of positive definite functions.

Kuibyshev Industrial Institute.

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MATHEMATICS

ON UNCONDITIONALLY CLOSED SETS

By A. MARKOFF

(Communicated by I. M. Vinogradow, Member of the Academy, 30. XII. 1943)

1. Definition 1. Let G by an arbitrary group. We say that a set $A \subset G$ is unconditionally closed in G if this set is closed with respect to any topology that may be defined in G.

Various questions concerning the theory of topological groups lead to the consideration of unconditionally closed sets. One of such questions will be pointed out below. The problem dealt with in the present paper is to characterize the unconditionally closed sets in terms of the abstract theory of groups.

2. Definition 2. Let G be a group, $A \subset G$. We say that A is an elementary algebraic set in the group G if there exist a positive integer m, a system $\{a_i\}_{i=1}^{m}$ of elements of G and a system of integers $\{\alpha_i\}_{i=1}^{m}$ such that

$$A = \mathop{\mathcal{E}}_{x} \left[\prod_{i=1}^{m} (a_i x^{\alpha_i}) = 1_G\right]$$

Definition 3. We say that A is an additively algeibraic set in the group G if A is the set-theoretical sum of a finite number of elementary algebraic sets in G.

Definition 4. We say that A is an algebraic set in the group G, if A is the intersection of a family of additively algebraic sets in G.

The following theorem is obvious:

Theorem 1. *Every algebraic set in G is unconditionally closed in G.*

The question arises, Whether the inverse theorem is true. The question may be answered in the positive provided that the group G is enumerable.

3. To formulate the results for this case we first introduce the notion of «the algebraic closure» in a group.

Definition 5. Let G be a group, $A \subset G$. Under the algebraic closure of A in G we understand the intersection of all algebraic sets (in G) containing A.

The algebraic closure of a set A in the group G is, evidently, the least algebraic (in G) set containing A.

Theorem 2. *For an arbitrary subset A of an enumerable group G a topology may be defined in G such that the closure of A with respect to this topology coincides with the algebraic closure of A in G.*

Corollary 1. Every set unconditionally closed in an enumerable group G is algebraic in G.

4. We say that the topologization of a group is trivial, if all subsets of the group are closed with respect to the topology introduced. The problem of existence of non-trivial topologizations of a group G is evidently equivalent to

the problem of unconditional closedness of the set $G \setminus (1_G)$ in G. Using the results obtained it is easy to give an algebraic criterion for the existence of a non-trivial topologization of an enumerable group.

Corollary 2. An enumerable group G admits a non-trivial topologization if and only if the totality of all the elements of this group different from the unity is not an additively algebraic subset of G.

The question remains open, Is this condition necessarily fulfilled? Or may there not exist enumerable groups for which the set $G \setminus (1_G)$ is additively algebraic? If such groups are possible, we should have enumerable groups admitting no topologization but the trivial one; if not, then every enumerable group admits a non-trivial topologization.

5. Consider another corollary of Theorem 2. Introduce first

Definition 6. Let G be a group, $A \subset G$. We say that A is potentially dense in G if G admits a topologization such that A becomes dense in G.

Theorem 2 gives an algebraic criterion for the set to be potentially dense in the enumerable group. Namely, we have

Corollary 3. A subset A of an enumerable group G is potentially dense in G if and only if the algebraic closure of A in G coincides with G.

Hence, in particular, a subset of the infinite cyclic group is potentially dense in this group, if and only if this subset is infinite itself.

6. Theorem 2 can be proved by constructing a suitable multinorm [1] in G.

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MECHANICS

ON FLYWHEEL DESIGN

By I. I. ARTOBOLEVSKY, Corresponding Member of the Academy

In modern engineering designs the problem of determination of the requisite flywheel inertia in a machine is usually solved approximately by the method of excess moment diagrams as suggested by Radinger (1). Another method in general use is to plot kinetic energy—reduced mass diagrams according to Wittenbauer (2). Radinger's method is very simple, but it gives only an approximate solution and its application is confined to the design of machines whose motion is characterized by low coefficients of unsteadiness; Wittenbauer's method is free from the assumptions made by Radinger, but it suffers from the disadvantage of entailing the necessity to plot a number of intermediate functions, which generally leads to considerable errors in the ultimate results. A solution similar to Wittenbauer's method has been proposed by Merzalov (3) and Gutjar (4).

It is the purpose of the present author to show that the method of excess moment diagrams can give a rigorous solution of the problem without resorting to the assumptions made by Radinger. So the use of this method does not depend upon whether the run of the machinery is characterized by a low or a high coefficient of unsteadiness.

As is well known (5), the equation of motion of a mechanism can be written in the general form as follows

$$M_d - M_r = I_r \frac{d\omega}{dt} + \frac{dI_r}{d\varphi} \frac{\omega^2}{2} \tag{1}$$

where M_d is moment of reduced driving force; M_r is moment of reduced resistance force; I_r is reduced moment of inertia of the mechanism; ω is angular velocity of the reduction link.

The reduced mass I_r of the mechanism can always be represented thus

$$I_r = I_0 + \Delta I_r \tag{2}$$

where I_0 is the constant moment of inertia of the flywheel which we have to determine; and ΔI_r is the reduced mass of all of the remaining links of the mechanism. Denoting the difference $M_d - M_r$ by ΔM, equation (1) can now be rewritten in the following form

$$\Delta M = (I_0 + \Delta I_r) \frac{d\omega}{dt} + \frac{d(\Delta I_r)}{d\varphi} \frac{\omega^2}{2} \tag{3}$$

Let us consider the positions of the mechanism in which the angular acceleration of its driving link is zero, $d\omega/dt = 0$. Clearly, in these positions the angular velocity is either at maximum, ω_{max}, or at minimum, ω_{min}. Accordingly, equations (3) for these positions will take the form

$$\Delta M' = \frac{d(\Delta I_r)}{d\varphi} \frac{\omega^2_{max}}{2} \tag{4}$$

$$\Delta M'' = \frac{d(\Delta I_r)}{d\varphi} \frac{\omega^2_{min}}{2} \tag{5}$$

Let us further show that the values on the right-hand side of equations (4) and (5) can always be determined without plotting a graph of reduced inertia moments, but merely from data obtained by a preliminary kinetic calculation of the mechanism.

In fact, the quantity ΔI_r is known ([6]) to equal

$$\Delta I_r = \sum_1^n \left[m_i \left(\frac{v_{Si}}{\omega}\right)^2 + I_i \left(\frac{\omega_i}{\omega}\right)^2 \right] \tag{6}$$

where m_i and I_i are mass and moment of inertia of an i-th link of the mechanism; v_{Si} and ω_i are the velocity of the centre of gravity S_i and angular velocity of this link. From equation (6) we get

$$\frac{d(\Delta I_r)}{d\varphi} = \frac{2}{\omega^*} \sum_1^n \left[m_{ri} l^2 \frac{a^{\tau}_{Si}}{v_{Si}} + I_{ri} \frac{\varepsilon_i}{\omega_i} \right] \tag{7}$$

where m_{ri} is reduced mass of the i-th link; I_{ri} is reduced moment of inertia; l is the length of the reduction link; a^{τ}_{Si} is the tangential acceleration of the centre of gravity S_i; ε_i is the angular acceleration of the i-th link assuming that the angular velocity ω^* rests invariable, its value in (7) being either ω_{max} or ω_{min}.

It may easily be seen that the ratios a^{τ}_{Si}/v_{Si} and ε_i/ω_i can be replaced by the respective intercepts taken from the velocity and acceleration diagrams. The values of these ratios are positive or negative according to the direction of the vectors $\overline{a^{\tau}_{Si}}$, $\overline{v_{Si}}$, $\overline{\varepsilon_i}$ and $\overline{\omega_i}$, yet their magnitude ratio for every position of the mechanism is solely a function of the driving link's rotation angle φ.

Substituting in (4) and (5) the value of the differential quotient (7) we have

$$\Delta M' = \omega_{max} \sum_1^n \left[m_{ri} l^2 \left(\frac{a^{\tau}_{Si}}{v_{Si}}\right) + I_{ri} \left(\frac{\varepsilon_i}{\omega_i}\right) \right] \tag{8}$$

$$\Delta M'' = \omega_{min} \sum_1^n \left[m_{ri} l^2 \left(\frac{a^{\tau}_{Si}}{v_{Si}}\right) + I_{ri} \left(\frac{\varepsilon_i}{\omega_i}\right) \right] \tag{9}$$

As the quantities under $\sum$ in these equations are equal, the functions $\Delta M'$ and $\Delta M''$ differ only in constant coefficients ω_{max} and ω_{min}. Consequently, by plotting the first function we also obtain the plot of the second to the scale $\mu = \omega_{max}/\omega_{min}$.

Let us now proceed to the determination of flywheel inertia when the coefficient of motion unsteadiness δ and the mean angular velocity ω_{mean} of the driving link are given.

We plot in an ordinary way the diagram of tangential forces or moments $M_d = f(\varphi)$ for the driving link as a function of its rotation angle φ (see figure). This plot corresponds to one full cycle of the steady motion period. Taking the area of this diagram with a planimeter we find the work of driving forces for a full cycle (in the present case a full cycle is supposed to be equal to 2π). We have

$$A_d = \int_0^{2\pi} M_d d\varphi$$

Assuming, as is usual in engineering designs, that the work of resistance forces is constant, we obtain the mean moment of resistance M_r from the

equation

$$M_r = \frac{\int_0^{2\pi} M_d d\varphi}{2\pi}$$

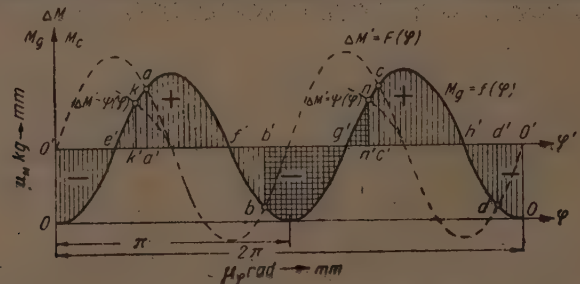
The curve obtained in the coordinate system $O'\Delta M\varphi'$ is that of the excess moment $\Delta M = \Phi(\varphi)$ as defined by equation (3).

By means of equations (8) and (9) we will determine $\Delta M' = F(\varphi)$ and $\Delta M'' = \Psi(\varphi)$. This may be done by substituting ω_{max} and $\omega_{m\,n}$ with their values expressed by coefficient δ and by the mean angular velocity $\omega_{m\,an}$ [5]. We have

$$\Delta M' = \omega_{mean}\left(1+\frac{\delta}{2}\right)\sum_1^n\left[m_{ri}l^2\left(\frac{a_{Si}}{v_{Si}}\right)+I_{ri}\left(\frac{\varepsilon_i}{\omega_i}\right)\right]$$

$$\Delta M'' = \omega_{mean}\left(1-\frac{\delta}{2}\right)\sum_1^n\left[m_{ri}l^2\left(\frac{a_{Si}}{v_{Si}}\right)+I_{ri}\left(\frac{\varepsilon_i}{\omega_i}\right)\right]$$

The function $\Delta M' = F(\varphi)$ thus obtained is plotted on an equal scale (dotted line in the figure) with the diagram $\Delta M = \Phi(\varphi)$. Obviously, the driving link



will have a maximum angular velocity at those positions of the mechanism for which $\Delta M' = \Delta M$, *i. e.* when the positions a', b', c' and d' are such that the curves $\Delta M = \Phi(\varphi)$ and $\Delta M' = F(\varphi)$ intersect at points a, b, c and d (see figure).

Examination of the figure will show that when the position of the mechanism is at a' or c' the angular velocities ω_{max} cannot possibly be at maximum, for the increment of kinetic energy in the interval $e'a'$ is less than that of the sum of kinetic energies in the intervals $O'e'$ and $O'h'$, and also less kinetic energy is acquired in the interval $g'c'$ than in $f'g'$.

Therefore in the positions a' and c' we shall have some arbitrary minimum angular velocities which we need not consider at this juncture. It is apparently in the positions b' and d' that the driving link will reach maximum angular velocities.

Just which of these two positions will correspond to the extremal value of angular velocity, is a question that may be solved in the customary way by comparing the areas comprised between these values. Suppose that the extremal value ω_{max} corresponds to the position at b'. Seing, further, that functions $\Delta M'' = \Psi(\varphi)$ and $\Delta M' = F(\varphi)$ differ in nothing but scale, the former can be plotted from the diagram of the latter by merely reducing the ordinates in the ratio $\mu = \frac{2-\delta}{2+\delta}$.

The plotting of $\Delta M'' = \Psi(\varphi)$ can be dispensed with for the whole range of the angle φ equal to 2π, for it is seen from the plot of $\Delta M' = F(\varphi)$ that in the positions a' and c' the angular velocity of the driving link takes some arbitrary maximum values. Because of smallness of δ the true position of

the driving link in which it has minimum angular velocities ω_{min} must obviously be somewhere near the points a' and c'. It is therefore sufficient to find several points of this curve in the vicinity of a' and c' including, of course, the position in which the function $\Delta M'' = \Psi(\varphi)$ intersects with $\Delta M = f(\varphi)$.

These portions of the curve comprising the intersection points k and n are shown in the figure. It will be obvious that at k' and n' the velocity of the driving link is a minimum because for these positions $\Delta M'' = \Delta M$.

Further, we may use the previous method to find the position in which the angular velocity takes the extremal value. Let this position be at n'. Then the moment of inertia of the flywheel I_0 is determined from the equation

$$I_0 = \frac{2\int_{\varphi_{min}}^{\varphi_{max}} \Delta M d\varphi - I_{r\,max}\omega_{max}^2 - I_{r\,min}\omega_{min}^2}{\omega_{max}^2 - \omega_{min}^2} \qquad (10)$$

where φ_{max} and φ_{min} are the rotation angles of the reduction link corresponding to the points b' and n'; $I_{r\,max}$ and $I_{r\,min}$ are, respectively, the reduced moments of inertia of the mechanism links (without flywheel) corresponding to the above angles φ_{max} and φ_{min}.

If $I_{r\,max}$ and $I_{r\,min}$ are small, one may use the approximate formula

$$I_0 \cong \frac{\int_{\varphi_{min}}^{\varphi_{max}} \Delta M\, d\varphi}{\delta\omega_{mean}^2} \qquad (11)$$

Note further that the problem of determining the function $\Delta M' = F(\varphi)$ and $\Delta M'' = \Psi(\varphi)$ can be solved as well by the customary kinetostatic method without computing the derivative of the reduced moment of inertia of the mechanism link. In fact, the second term on the right-hand side of equation (3) taken with reverse sign is nothing else but the moment of all inertia forces of the mechanism reduced to the driving link which is supposed to move permanently, *i. e.* with constant velocity ([6]).

The function $\Delta M' = F(\varphi)$ can be found by ordinary methods of kinetostatics, whereby the forces of inertia of individual links are determined on the assumption that the driving link revolves with a constant angular velocity equal to ω_{max}; the reduction of the forces of inertia to the driving link is made by means of the rigid lever theorem. Functions $\Delta M'' = \Psi(\varphi)$, as has been mentioned above, will be found by simple conversion of the scale.

To conclude it is well to point out that once the moment of inertia of the flywheel has been determined and we have found the positions b' and n' in which the velocity of the driving link takes the values ω_{max} or ω_{min}, respectively, the angular velocity $\omega_{p'}$ of the driving link in any position p' can be determined from the equation

$$\omega_{p'} = \sqrt{\frac{I_0 + m_{rb'}l^2}{I_0 + m_{rp'}l^2}\omega_{max}^2 - \frac{2}{I_0 + m_{rp'}l^2}\int_{\varphi_{p'}}^{\varphi_{b'}} \Delta M\, d\varphi} \qquad (12)$$

The quantities $m_{rp'}$ and $m_{rb'}$ are reduced masses of the mechanism link in the respective positions p' and b'.

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PHYSICS

ON THE ORIGIN OF IONIZATION BURSTS (HOFFMANN STÖSSE) OBSERVED AT HIGH ELEVATIONS

By D. W. SKOBELZYN, Corresponding Member of the Academy

The problem of ionization bursts, if its treatment is intended to cover the whole range of the subject, appears to be a matter of considerable complexity. It may be well therefore to begin the present discussion by considering the simplest conditions which take place when the observation is carried on with thin-walled ionization chambers having no massive screen above them.

It has already been shown by the author that the number of bursts per unit time is in good agreement with the results obtained by a calculation based on the number of Auger showers recorded by the coincidence method at sea level.

A very different result is obtained if the computed values are compared with those observed at a considerable height above sea level. Upon comparing the levels corresponding to two different points of the altitude curve for Auger showers ($t=17$ and $t=26$), to which our former computations relate (1), one may anticipate an increase of the number of bursts as high as three to four times only, whereas the experiment, according to the data secured by Montgomery(2), gives an increase of more than fifty times. If, as we have seen, the bursts detected in the Montgomery chamber at sea level correspond in order of magnitude to computation, nevertheless the comparison of the computed results with the data obtained with the same chamber at the altitude of Jungfrau shows a divergence of more than twenty times. And the difference amounts to several hundred and even a thousand times when the computed results are compared with the data of very small chambers ($\sigma=50$ cm^2), such as have been used by Young *.

So strong a divergence speaks against the assumption that bursts observed at high altitudes mark the passage of Auger showers through the cross-section of the ionization chamber.

Another hypothesis that suggests itself connects the ionization impulses arising in the chamber with the action of strongly ionizing «heavy» particles. This hypothesis can be checked on the basis of simple similarity relations which should become apparent when the results of observations made with chambers of different size are compared.

If the bursts are due to extensive showers (Auger showers) whose cross-section is large in comparison with the dimensions of the chamber (assumption 1°), then, the number of bursts ν per unit time being given, their size N will be proportional to the cross-section area of the chamber σ. The relation $\nu=\varphi\left(\frac{N}{\sigma}\right)$ in this case is independent of the dimensions of the chamber recording the bursts. Since,

* The disagreement with data of Young chambers (3) does not vanish, though it is lessened to a considerable extent, when observations made at sea level are compared. In this case, however, the background of parasitic impulses due to α-rays may have a certain influence.

according to empirical data, this dependence appears in a logarithmic diagram as a straight line, the points corresponding to observations made in chambers of different size should fit into a single straight line, which, as found out by Carmichael and Chou [4], is actually the case when the results of observations made at sea level are brought into comparison.

If, on the other hand, the effect is caused by separate strongly ionizing particles (or some kind of burst showers arising in the wall of the chamber) (assump-

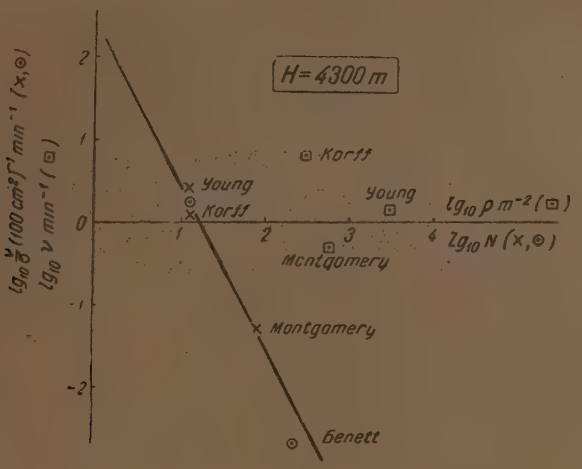

Fig. 1

tion 2°), the data of different chambers can be brought into coincidence and reduced to a common straight line while plotting $\lg \frac{\nu}{\sigma}$ as a function of $\lg N$. In other words, if we consider the relation between $\lg \nu$ (ordinate) and $\lg N$ (abscissa), the straight lines that fail to coincide when observations were carried out in chambers of different dimensions, are made to do so by translation of the whole right line through a certain interval $\left(\text{equal to } \lg \frac{\sigma_2}{\sigma_1}\right)$, provided the translation is p a r a l l e l t o t h e a b s c i s s a a x i s in the case 1°, and t o o r d i n a t e a x i s in the case 2°.

In Fig. 1 are given data for three observers* ([2], [3], [5]) relating to a height of about 4300 m. As is seen, the records of the different chambers (the difference in the dimensions of the cross-sections amounts to more than 20 times) coincide very accurately when represented diagrammatically, according to the case 2° (crosses and circles in Fig. 1). This coincidence is impossible when the same values are plotted on the diagram of type 1° (squares in Fig. 1).

It should be borne in mind that either of the extreme points in Fig. 1 (observations by Young and Mongomery) represents a whole set of values fitting within a certain intercept of the straight line $\lg \frac{\nu}{\sigma} \rightarrow \lg N$; thus, the slope of this line corresponding to the relation $\nu \sim \frac{1}{N^2}$ is determined by the results obtained by each of the above-mentioned observers separately (the unit area in plotting this graph has been put at 100 cm²).

Graph 1 speaks rather unambiguously in favour of the assumption 2°. A direct corroborative evidence of this assumption is obtained by taking into account

* These data are recalculated on the assumption that the mean particles of cosmic radiation create 60 ion pairs per 1 cm of path in the air under normal conditions.

the observations made by Auger (6) with a Willson chamber controlled by counters placed as wide apart as 1—4 meters (altitude of Jungfrau). The right line of Fig. 2 corresponds to values yielded by calculation. The crosses designate the records of Auger's chamber ($\sigma = 400$ cm^2). The figures that stand by the crosses give the number of tracks on the photographs obtained by Auger (ν is the number of photographs per unit time with a number of tracks N exceeding the values given on the figure). If one disregards fluctuations, the ratio $\frac{N}{\sigma}$ defines the density of the stream of particles in a shower that has crossed the chamber. If $N \gg 1$, the probability that every shower crossing the chamber will hit the counters and thus place itself on record, is near to unity.

Excluding only two showers of very high density (more than 750 tracks)* the points corresponding to a simultaneous crossing of the chamber by several (more than 4—6) particles fall very close to the straight line representing the results of computation **. Contrary to this, the points designated by circles (ionization chamber) are seen to lie far away. This circumstance speaks strongly in favour of the second assumption.

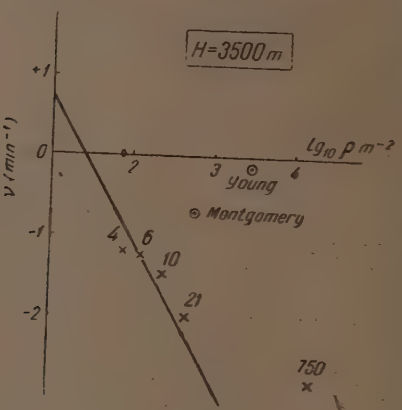

Fig. 2

The question as to the bursts observed in chambers provided with a lead lining is more complicated. In Fig. 1 the crosses designate points corresponding to observations made with such chambers [Young (3) with a lead filter 20 cm thick, and Benett, Brown and Rahmel (5), with 12 cm of lead]. The fact that these points lie very close to the curve representing the observations made with thin-walled chambers, is perhaps a matter of chance. It is, however, more likely that at high altitude and in the presence of a thick lead screen the bursts lying within the range of magnitudes considered by us, are due mainly to the same factor which operates also when there is no lead screening.

However that may be, there are two facts which speak very definitely against the assumption that ordinary ionization showers of cascade origin — so-called «ionization showers» — may manifest themselves in these bursts.

In the first place, an analysis of the entire accumulation of experimental data leaves no room for doubt but that the probability of the appearance of bursts in the presence of lead grows with the altitude much more rapidly than does the intensity of the corresponding penetrating component ***. Secondly, the absolute number of bursts per unit time is well above that which would correspond to the customary mechanism of formation of the secondary soft radiation in lead.

Knowing the relation $\nu = \varphi(N)$, one may easily obtain the curve bringing out the ionization effect connected with bursts exceeding the quantity N. In accordance with the curve of Fig. 1 we obtain a curve (Fig. 3) for the ionization value (referred to unit density of the penetrating component) as a function of N. On the ordi-

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* The appearance of two such showers in the above set of Auger's observations is puzzling. If the abnormally frequent occurrence of showers of such a high density will be confirmed by a high number of observations, this fact must be given special attention.

** The values represented in Fig. 2 refer to a height of $\approx$ 3500 m. A similar result is obtained in analysing the analogous experiments of Janossi and Lovell (7) made at sea level.

*** This is especially true of altitudes higher than 3000 m. The growth with altitude appears to depend upon the magnitude of the recorded bursts. According to Young (3), the increase is 9—20 times ($N > 10$—30) for altitudes ranging from sea level to 4300 m, whereas the intensity of the mesonic component of the same energy may increase only 1.5 times, if we take into account the well-known constant of mesonic disintegration ($\tau_0 \approx 2 \times 10^{-6}$ sec.).

nate axis is plotted the ionization effect expressed in terms of the number of ion pairs per cubic cm per second, and in per cent of the intensity of the penetrating group—i_D *.

The experimental data refer to the solid portion of the straigh line which corresponds to $N \geq 10$. By extrapolating to $N=2$ one may estimate the total ionization produced by the showers, or else, by strongly ionized particles different from those of the penetrating component.

Extrapolation along the straight line of Fig. 3 is not quite reliable. Still a certain lower limit for the total value of the additional ionization connected with the secondary radiation responsible for the appearance of bursts can be derived according to the following scheme, from some simple considerations, taking energy balance into account (in case the secondary radiation is generated by δ-particles).

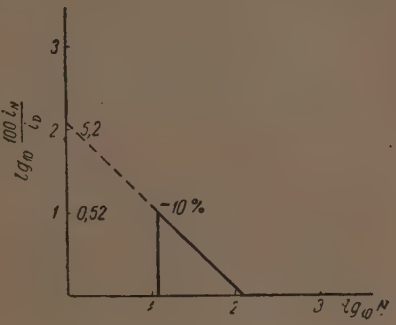

Fig. 3

In order that a secondary electron formed in the lead might create a cascade consisting, at the cascade curve maximum, of 10 or more ionizing particles, a mean energy higher than 4×10^8 eV is necessary.

From this one may conclude that an ionization produced by showers consisting of more than 10 particles (continuous line, Fig. 3) makes up but a portion of the total ionization due to secondary radiation arising from such collisions (mesons with electrons of the absorbing medium) as are accompanied by transfer of energy higher than 4×10^8 eV.

Let us denote by i_ε the quantity of the ionization effect created by secondary radiation due to δ-electrons which arise from collisions, in which energies higher than ε are transferred.

The lower limit for the ratio of the total secondary ionization $i_{\varepsilon\,\min}$ to i_ε can be evaluated on the assumption that $i_\varepsilon \sim \lg \varepsilon_{\max} - \lg \varepsilon$; $\varepsilon_{\max}$ be the maximum energy transferred on the collision of a meson with an electron. $\lg \bar{\varepsilon}_{\max}$ is the value averaged over the respective region of the energy spectrum of mesons. $i_{\varepsilon\,\min} - \lg \frac{\bar{\varepsilon}_{\max}}{\varepsilon_{\min}} \varepsilon_{\min}$ should be assumed to be equal to the energy corresponding to a path of a secondary electron exceeding the dimensions of the ionization chamber. If, keeping always in mind the evaluation of the lower limit, we put $\varepsilon_{\min} = 10^6$ eV, we will arrive by the above-mentioned way at the factor

$$\frac{\lg \varepsilon_{\max} - \lg \varepsilon_{\min}}{\lg \bar{\varepsilon}_{\max} - \lg \varepsilon} = 6.$$

If $i_\varepsilon > 0.1 i_D$ (according to the curve of Fig. 3), then

$$i_{\varepsilon\,\min} > 0.6 i_D \qquad (1)$$

Now i_D is the total intensity of the penetrating component, measured in terms of the current in the lead protected ionization chamber

$$i_D = i_m + i_{\varepsilon\,\min} \qquad (2)$$

where i_m is the ionization effect of mesons, *i. e.* the intensity of the hard component proper.

** The value $i_D = 5.2\ I$ corresponds to the data of Street and Young. This value is probably an overestimation. According to other data, it is possibly equal to 3.5 I.

According to (1) and (2)

$$\frac{i_{\epsilon\,\min}}{i_m} > \frac{0.6}{1-0.6} = 1.5$$

The obtained value is at least five times as great as that which would be compatible with the customary conceptions as to the normal mechanism of absorption.

From the assumption made in calculation, the value 1.5 is possibly a wide underestimate*.

It would seem that we have here to deal with some component of ionizing radiation characterized by a sharp growth with altitude and a very low absorption by lead. It is this abnormal absorption ratio (in lead and in atmosphere) that was noted by Heitler and Powell ([9]) on observing heavy particles by the photographic plate method. Observations in Wilson chamber appear to lead to the same results (with respect to the heavy particles) ([10]).

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* The possible influence of fluctuations is overshadowed by other factors which we omit here from consideration; these factors are known beforehand to act in the opposite direction.

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OCEANOLOGY

DISTRIBUTION OF BRACKWATER PLANKTONIC FAUNA IN SIBERIAN POLAR SEAS

By B. G. BOGOROV

(Communicated by P. P. Shirshov, Member of the Academy, 25. I. 1944)

Typical inhabitants of waters strongly freshened by continental discharge play an important part in the plankton of Siberian polar seas. Being widely distributed through the Siberian polar seas, this brackwater fauna is of great importance in the biomass of zooplankton. As to its origin, it is a typical autochtone fauna of Siberian seas, widely differing in this respect from other components of the zooplankton of Siberian seas, whose origin is related to the Atlantic, Arctic and Pacific oceans.

Among the most widely distributed representatives of this brackwater fauna are two small copepods, *Limnocalanus grimaldii* and *Drepanopus bungei*. Their ecological nature is well illustrated by the table showing the variation in their frequency as dependent on salinity.

S ‰	> 33	32—27	26—21	20—15	14—9	8—3	2—0
Limnocalanus grimaldii	—	2	17	36	30	100	12
Drepanopus bungei	—	1	16	72	54	100	37

We see that though these copepods occur over a wide range of salinities, the prefer lower salinities. Thus, their «brackwater» nature is quite evident.

Making use of literary data ([1-5]), his own data and material of the hydrobiological laboratory of the Arctic Institute, the author was able to compile a detailed map of the distribution of the above species (see figure).

The map is based on materials of the following expeditions: 1) «Zarya», 1900—1903; 2) «Andrej Pervozvannij», 1906; 3) «Taimyr», 1914; 4) «Taimyr», 1915; 5) Yenisseisk scientific fishery expedition, 1921—1923; 6) «Malygin», 1921; 7) «Taimyr», 1921; 8) «Bjelukha», 1930; 9) «Sedov», 1930; 10) «Bjelukha», 1931; 11) «Russanov», 1931; 12) «Russanov», 1932; 13) «Sibirjakov», 1932; 14) «Taimyr», 1932; 15) «Litke», 1934; 16) Polar station on cape Cheluskin in 1934 and 1935; 17) Scientific fishery expedition of the General Office of the Northern Sea Route, 1935, and 18) «Malygin», 1935.

As *Limnocalanus grimaldii* and *Drepanopus bungei* are the two most widely distributed species of the brackwater fauna of zooplankton of Siberian seas, we may consider their habitat as the region of distribution of the whole brackwater complex.

The area of distribution of the brackwater fauna in different seas is distinguished by specific peculiarities. This area is the widest in the Kara Sea. Occurrences are recorded from the Jugorsky Shar (probably, as an effect of Pechora waters). There are no materials from the Bajdarakskaya bay, but the occurrence there of brackwater fauna may be expected. It inhabits all the southern and eastern parts of the sea. In the character of distribution two main arms may be distinguished with a centre of distribution in the Obj-Yeniseisk-Pjassinsk region. One mighty arm is directed northwards, off the Jamal peninsula, to the northern end of Novaya Zemlya; the other stretches eastwards to the Severnaya Zemlya, through the whole southern and eastern part of the Kara Sea, and enters the Vilkitzky strait. Both arms meet in the southern part of the strait and penetrate farther East to the north-eastern part of the Taimyr peninsula.

In the Laptev Sea the brackwater fauna is lacking in its western part (in the region of Eastern Taimyr). We have no materials from the inshore waters of this

Map of distribution of brackwater planktonic fauna in Siberian polar seas. Unbroken line — limits of distribution; ×, *Limnocalanus grimaldii;* ● *Drepanopus bungei*

séa, but probably representatives of brackwater fauna occur near the shore, so that there is no complete break in its distribution in the Laptev Sea.

Limnocalanus grimaldii and *Drepanopus bungei* are very common in the region of the Lena river and the whole eastern part of the Laptev Sea. Probably, they also occur at the Novosibirsk islands for which no data are available. In the Eastern Siberian Sea the brackwater fauna follows the shore, its distribution reproducing the configuration of the coast. In the Chukotsk Sea its distribution is confined to the most western part of the sea, where it is of little importance and occurs but rarely.

No representatives of this characteristic Siberian brackwater fauna are recorded from the American part of the Northern Arctic Ocean.

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PHYSICAL CHEMISTRY

RATE OF CORROSION AND ELECTRODE POTENTIALS OF MAGNESIUM AS AFFECTED BY pH OF SOLUTION

By G. V. AKIMOV, Corresponding Member of the Academy, and I. L. ROSENFELD

One of the fundamental problems in studying the corrosion of metals is how the rate of corrosion and the electrode potential are related to the pH of the solution. In the present investigation this problem is discussed in relation to magnesium. The rate of the corrosion process was estimated volumetrically.

The apparatus the authors used for this purpose bears a certain resemblance to that devised by Portevin, Pretet et Jolivet[1]. In it the reaction vessel is separated

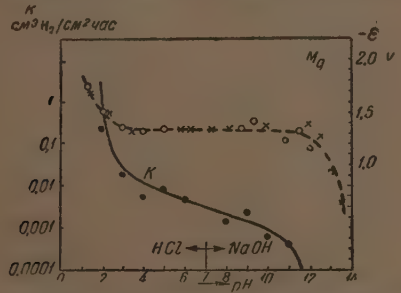

Fig. 1. Rate of corrosion and electrode potential as affected by pH of solution

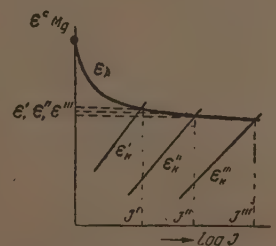

Fig. 2. Constancy of potential at different rates of corrosion (corrosion currents I', I'' and I'''). Cathodic polarization curves E_n', E_n'', E_n''' refer to solutions with increasing concentration of hydrogen ions

from the measuring part, which makes it possible accurately to control the temperature and, if necessary, to take readings not only from a burette but also from much the more sensitive micromanometer. The experiments were run with different solutions of NaOH (pH from 7 to 13. 5), with distilled water and with HCl solutions (pH from 7 to 2).

The results obtained are represented in Fig. 1. On the ordinate axis is marked off the rate of corrosion in logarithmic coordinates and the electrode potential in ordinary coordinates. Every point is an average of 3 to 6 tests. The crosses and circles designate two independent sets of tests concerned with determination of electrode potentials. This plot may be separated into three different regions. The first—from pH=3 downwards—is characterized by a sharp increase of both the corrosion rate curve and the electrode potential curve. In this strongly acid region no protective film can probably exist on magnesium, and the rate of corrosion is determined by the intersection of hydrogen overvoltage curve relating to cathodic areas—impurities (cathodic curve) with the curve of anodic polarization of magnesium.

That there is no protective film of any importance on magnesium in a strongly acid solution has also been proved by Clark and Akimov (2). Abrasion of the magnesium in their experiments failed to affect the potential which lay invariably about—1.6 V. However, if there is no formation of protective film in this strongly acid region, we are left nothing to account for the sharp rise of the potential curve toward the negative side or for the equally abrupt rise of the corrosion curve.

The second region stretches from pH=3 to pH=11. Here the corrosion curve runs more smoothly. Still the transition from pH=3 to pH=11 is marked by quite an appreciable change in the rate of corrosion—as great indeed as nearly 100 times. But the value of electrode potential in this region is practically invariable.

It would seem that the protective film is a rather important factor in this region. Thus, the increase of the rate of corrosion with increasing concentration of hydrogen ions appears to be connected not merely with the increase of the potential on cathodic areas, but also with the growth of the effective area of the metal subjected to the action of the acid.

In neutral solutions the influence of the film becomes apparent. This has again been brougth into evidence by the experiments of Clark and Akimov (2), who have observed the abrasion to change the potential toward the negative by as much as 60 to 80 mV.

The constancy of the measured potential in this region can be explained by the closeness of the general potential to that of the anodically polarized magnesium (Fig. 2).

Finally, there is a third, strongly alkaline, region which begins from pH=11 and extends upwards of this value. This region is characterized by the protective film strongly increasing in stability, owing to which the rate of corrosion drops abruptly and the potential curve shows a sharp bend toward the positive side. With pH=11.5 the rate of corrosion is no longer measurable even by means of the very sensitive volumetric procedure. Clark and Akimov data also testify to the great significance of the protective film in this region—the abrasion changed the electrode potential by 300 to 800 mV.

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GEOLOGY

THE PALAEOGENE OF BORDOBA (TRANS-ALAI RANGE)

By O. S. VIALOV

(Communicated by W. A. Obruchev, Member of the Academy, 27. III. 1944)

In 1934 V. P. Renngarten described a Tertiary section near Bordoba. At that time there was no stratigraphical scheme of the Palaeogene of Central Asia, neither was there any knowledge of the oyster fauna. V. P. Renngarten was therefore unable to establish the precise age of the separate parts of the section and to correlate it with other Tertiary sections. In July 1943 at Bordoba the author examined the northern and southern sections of the Palaeogene. After a personal acquaintance with the Palaeogene of Bordoba and some new findings of fauna, the author gives a new treatment of this section which may be included in the cumulative Central-Asiatic scheme of the stratigraphy of Tertiary deposits (3).

The northern section on the right bank of the At-Djailyau river opposite the Bordoba post is as follows: the limestones with radiolites referring to the Maestrichtian substage are overlain by a series of gypsums which seem to be analogues of the Goznau gypsum of Ferghana (Danian stage). Higher up lie:

The Bukhara stage—black laminated limestones. In the section of Bordoba it is 5 m thick, but in other parts of the Trans-Alai range a thickness up to 50 m is recorded (2).

The Suzak stage. After V. P. Renngarten, the black limestones are overlain by soft grey marls, poorly exposed. In this part of the section the slopes are almost completely covered with sod; at some places debris of soft black calcareous clays and fragments of loose green sandstones are observed. Fine specimens of *Ostrea hemiglobosa* Rom. found in the talus for the first time establish beyond any possible doubt the Suzak age of these clays.

The Alai stage begins with layers of thick-bedded limestones, in the lower part arenaceous, with a light greenish shade. The limestones contain many oysters, belonging probably to the *Ostrea multicostata* Desh. group. It was not possible to break out specimens for an accurate determination. The thickness of these limestones protruding in the form of a distinct cornice is 8 m. Higher up there lies a rather thin intercalation of red clayey laminated sandstones and arenaceous clays (about 5 m). Further on, an alternation of grey clay shales and limestones with scarce oysters (15—20 m) is observed. This intercalation is followed by a new sharp cornice of solid grey limestones (17 m) carrying oyster shells. Subordinate to these limestones is a bed of shell rock, consisting of *Ostrea turkestanensis* Rom., its variety var. *alaica* Vial., *Ostrea cizancourti* Cox, *etc.*

The Turkestan stage is represented by grey clayey shales with bands of solid limestones; in the middle portion of the exposed series a two meter thick bed of limestone with a large number of oysters is traced. It was already dark when we reached this limestone, and we succeeded in securing a specimen of *Liostrea kokanensis* Sok. which testifies to its belonging to the Turkestan stage.

V. P. Renngarten reports from this horizon (layer *i* of his section) *Ostrea strictiplicata* Raul. et Delb., large-sized smooth *Ostrea* sp. (ex gr. *O. sewerzowi* Rom.) and *O. kokanensis* Sok. At present we know that all these species are characteristic of different stages of the Palaeogene and cannot possibly occur in the same horizon ([3],[4]). There is no doubt that the determinations of these oysters made at that time by A. R. Burachek and the present author were incorrect. The taxonomy of Central Asia oysters was not yet developed, and their distribution according to horizons was not established with sufficient accuracy.

The overlying grey clayey shales sheared by the overthrust were formerly referred to the Oligocene ([5]). I refer them to the Turkestan stage of the Eocene on ground of the following considerations.

The presence within the Alai stage, between two series of limestones, of a horizon of red rocks is of great interest. A similar horizon has been recorded also in the more eastern sections. It is known also in the Tadjik depression, for instance in the sections which are transitional from the central type (Aruk-tau) to the eastern Darvaz type (Khirmandjou) ([5]). We shall return to this horizon later. A somewhat different section is observed in the middle zone, beginning 5 km south of the Bordoba post. It will be described here after V. P. Renngarten, but treated anew, in more detail, complemented with a list of new findings of fauna, permitting of age determinations.

The Danian gypsum beds are overlain by:

The Bukhara stage: dark-grey solie laminated limestones, 5 m.

The Suzak stage: thick-bedded grey sandstones; in the lower part of the series there are thin intercalations of grey clayey shales.

The Suzak-Alai stages. Red clayey shales and sandstones. A similar red-bed horizon but of a considerably lesser thickness has been recorded also in the previous section under the Lower Alai limestone. If the two horizons be considered as stratigraphic analogues, in the given section it should also be referred to the Alai stage. Moreover, referred to the same stage should also be the upper portion of the beds of grey sandstones which should be then regarded as an analogue of the Lover Alai limestone of the northern section. However, in the upper part of the sandstone beds neither any evidence of Alai fauna nor any marked difference from the remainder of these beds has been discovered.

It seems to the author that it would be more correct to refer the red beds to the Suzak stage. The writer has described in another paper some sections of the Alai range ([6]). Near the village of Kizyl-Kurgan on the Pamir tract the Suzak stage consists of two parts: the lower part is represented by grey and greenish sandstones and arenaceous clays; and the upper one, by alternating red clays, sandstones and gypsum. Here a transition is seen to the sections of Southern Ferghana, where the Suzak stage is represented by red gypsum-bearing beds. Similar relationships are much likely to exist in the middle zone of Bordoba, too; as compared to the northern zone it lies nearer the shore.

It should further be noted that in the general section of the northern zone B. A. Borneman and S. A. Ovchinnikov report a red-bed intercalation below the limestones with Alai oysters. It may be that also in the northern section of Bordoba there are two red-bed intercalations—Alai and Suzak, but the latter is hidden under the talus and the sodded part of the slope.

The Alai stage. The unquestionable Alai stage begins with an intercalation of limestones, now black, and now light-grey, with a yellowish surface of weathering (12 m). The limestones are thick-bedded, separated by thin bands of marls, containing remains of costate oysters from the group *Ostrea multicostata* Desh. and *O. turkestanensis* Rom. Following higher up, there are grey schistose marls with subordinate limestone bands (32 m). A thicker bed of limestone (4 m) in the lower part of this pocket carries oyster banks (two intercalations) consisting of *Ostrea turkestanensis* Rom.

The Turkestan stage consists of three parts. In the lower part there are grey compact limestones alternating with grey marlaceous shales with a slate-like parting. V. P. Renngarten points out rare findings of very large-sized

smooth *Ostrea* (layer *h* of his section). Of the oyster fauna discovered here by the author the following have been determined: *Fatina exterhazyi* Pav., *F. böhmi* Vial. and *Liostrea kokanensis* Sok. These oysters permit to fix with great accuracy the Turkestan age of the beds. The thickness of the packet is 54 m. Along its roof V. P. Renngarten draws the boundary between the Eocene and the Oligocene (?). This boundary should be now shifted considerably higher up.

The middle part of the Turkestan stage is represented by a packet of grey calcareous schistose sandstones, more or less argillaceous (13 m). The sandstones are overlain by a packet of clayey shales, calcareous, occasionally somewhat arenaceous, finely laminated (up to 70 m).

The Rishtan stage. White gypsum, in the lower portion with thin bands of schistose clays (45 m). The section terminates in this horizon, composing the core of a steep squeezed syncline. The gypsum beds are referred to the Rishtan stage on the basis of a correlation with the sections of the Tadjik depression where this stage consists of two parts—a lower packet of gypsum and an upper one of crimson clays ([5]).

The Palaeogene of the southern zone of the northern slope of the Trans-Alai range was not examined by the author. It is of interest to note only *Platygena asiatica* Rom., found by D. V. Nalivkin and P. P. Chuenko ([7]) in the valley of the Koksu river (the left tributary of the Kizyl-art river), and by V. P. Renngarten in the talus of one of the Palaeogene belts, appearing within the area of development of red beds of the Tertiary. From these findings, V. P. Renngarten assumes here the presence of Oligocene([7]), while the two former investigators are inclined to correlate the strata carrying this oyster with the higher lying red-beds [([7]), p.24]. It is not possible at present to make a revision of the old collections of the writers named and to check up the correctness of the determinations made by them. If it be really *Platygena asiatica* Rom., there is an evidence of the presence of the Rishtan stage in the marine facies. Since from the sections of the Tadjik depression it appears that the Rishtan sea was the most shallow-water one, we are justified in expecting here the presence of other stages of the Palaeogene also in the marine facies; the rocks composing them may be red coloured. A similar section was observed by the author in the Alai range, south of Sufikurgan (the Kunek-sogdy river).

Thus, the sections of the central part of the northern slope of the Trans-Alai range suit very well the stratigraphic scheme ([3]) of Tertiary deposits of Central Asia. In the sections examined by the author, all the stages from the Bukhara to the Rishtan are distinguished.

From its nature and some elements of the fauna (*Ostrea hemiglobosa* Rom. is quite a typical form but not the Ferghana variety) the sections of the Trans-Alai range are much nearer the Tadjik depression than Ferghana. And this is quite natural, since they are located in that area of development of the Palaeogene which stretched along the strike from the Tadjik depression through the Range of Peter the Great and the Trans-Alai range to Irkeshtam and further on.

It should only be mentioned that *Platygena asiatica* Rom., characteristic of the Palaeogene of Ferghana, failed as yet to be encountered in the Tadjik depression. It has been found, too, that it is widespread enough in the Alai range.

V. P. Renngarten has already pointed out that in passing from North to South and from one zone to another (*i. e.* to the Pamir) the approach to dry land is distinctly felt [([7]) p. 23]. A similar conclusion has been reached by the author ([5]) concerning the western extension of the same belt (eastern part of the Tadjik depression and Darvaz).

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MINERALOGY

NEW OBSERVATIONS ON THE RESULTS OF GRAVITATIONAL SHIFTING OF CRYSTALS IN VEINS OF ALPINE TYPE IN THE NEAR-POLAR URALS

By D. P. GRIGORIEV

(Communicated by A. E. Fersman, Member of the Academy; 2. II. 1944)

At the Near-Polar Urals one may distinctly observe in veins of the Alpine type the results of gravitational shifting of crystals of different minerals, which took place during the formation of these veins (1). Once detached from the hanging wall of the veins the crystals and their fragments would sink down. The same probably occurred both to the crystal embryos and minute crystals which formed in the aqueous solution filling the vein.

The results of the phenomena referred to are manifest in minerals as three distinct features: (1) s p r i n k l i n g of the rock crystal faces, which had been previously turned upward, with minute crystals and fragments both of rock crystal and of other vein minerals—chlorite, sericite, carbonates, while the lower faces shielded by the body of the crystals remain quite clean; (2) the existence of so-called g h o s t s—areas of the surface of such crystals as had been shielded from above by other crystals, overgrowing rock crystal; and (3) distinct evidence of the existence in the aqueous solution filling the veins * of ascending and descending convection currents affecting the development of the h e a d of rock crystal and the nature of the surface of their faces (accessories of growth).

While studying a specimen in the collection of rock crystal from Alpine type veins of the Near-Polar Urals, obtained by the author from Dr. G. G. Laemmlein and V. N. Chernova, geologist, the author has discovered new and rather peculiar results of a gravitational shifting of crystals.

The specimen, a sketch of which is given in Fig. 1, is represented by an irregular fragment of a rock crystal with inclusions of fibrous amphibole—byssolite and prochlorite **.

The r o c k c r y s t a l in the specimen is by itself quite colourless and transparent.

The b y s s o l i t e is represented by very fine (hundredth fractions of a millimeter) curved fibres attaining a length of 50 mm. The fibres form an aggregate resembling a very loose felt.

The p r o c h l o r i t e is present in the specimen in the form of dirty-green small hexagonal flakes (tenths of a millimeter), irregular pieces, or as columnar, straight or vermicularly sinuous crystals («vermiculites»), up to 1 mm long.

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* Secondary inclusions of the liquid mineral are very common in rock crystal(2,3).

** Both minerals are very frequent inclusions in Uralian rock crystal. An interesting example see in (4).

The general relations between the minerals described are as follows. The felted byssolite pierces the entire lower part of the rock crystal fragment, while the upper portion of the specimen is free from its fibres. The prochlorite occurs only in the upper part of the felt-like aggregate of byssolite, never occurring in the zone of pure quartz.

Closer observations of the relations between the minerals permit to trace the following picture of their formation.

Out of the three minerals, chlorite was the first to form; it probably covered all the vein walls. Later on fibres of byssolite began to grow; in the case considered

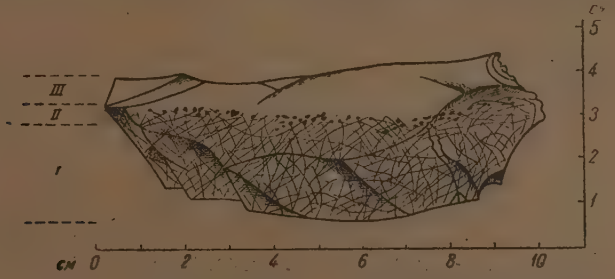

Fig. 1. Crystal fragment of rock crystal with inclusions of byssolite and prochlorite. *I*, zone with inclusions of felted byssolite aggregate; *II*, zone with flakes and small crystals of prochlorite in the upper part of the zone with byssolite; *III*, zone of pure rock crystal

they were located on the lower surface of the vein, forming «thickets» of interweaving fibres, resembling an accumulation of sinuous algae at the bottom of a still

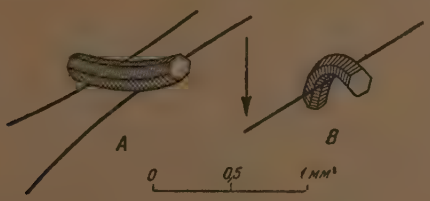

Fig. 2. « Suspended crystals». *A*, slightly curved crystal, freely resting upon two byssolite fibres; *B*, curved crystal of prochlorite—vermiculite suspended at a byssolite fibre. Arrow indicates the retraced trend of gravity (direction of sinking of crystals)

water basin. For some reason or other the flakes and crystals of prochlorite would become detached from the hanging wall of the vein and sink under the action of gravity; they would reach the byssolite aggregate and become entangled in its interweaving fibres on the upper surface (in the case of crystals of a somewhat larger size), or drop to some 1—3 mm deep until they reached more densely interwoven fibres (in the case of small flakes). This is evidenced by the fact that under the magnifying glass in the uppermost portion of the byssolite layer in the specimen small crystals of chlorite are visible lying freely upon byssolite fibres, as shown in the drawing (Fig. 2, *A*), or even hanging upon one fibre (as in Fig. 2, *B*). Observations made both on these crystals and on others showed all of them to have fallen in the same direction.

After having sunk the prochlorite did not continue to grow—it is never found to grow around byssolite fibres. Later on, the peculiar aggregate of byssolite and chlorite was captured and retained by the quietly grown crystals of rock crystal.

These observations of the results of gravitational shifting of crystals constitute the fourth group of evidence in favour of the existence of this process; the character may conveniently be termed that of s u s p e n d e d c r y s t a l s.

The cases of gravitational shifting of crystals described by the present author and reported in literature are of unquestionable interest for mineralogy and geology. They belong to the «mineralogical plumb-lines» and «mineralogical levels», permitting of an objective and accurate determination of the trend of gravity at the moment of crystal formation; when observed *in situ*, they make it possible to trace the original position of the vein in space. The great importance of this kind of determinations for various tectonic structures is obvious. Phenomena of this kind should be thoroughly studied and described.

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PLANT PHYSIOLOGY

FREQUENCY OF TRANSGRESSIONS OF WINTER HARDINESS IN WHEAT HYBRIDS

By M. I. SALTYKOVSKY and E. S. SAPRYGINA

(Communicated by A. A. Richter, Member of the Academy, 31. I. 1944)

The inheritance of winter hardiness in wheat hybrids has the reputation of being one of the most intricate problems in genetics and plant-breeding. Nilsson-Ehle (Sweden), to whom the study of the inheritance of physiological characters in plants owes its foundation, believed winter hardiness to be a polymeric character dependent on a large number of equivalent factors. On the ground of his theory Nilsson-Ehle came at the conclusion ([1]) that in order to obtain hybrids exceeding in winter hardiness the original parental varieties, it is necessary to bring the number of F_2 hybrids to no less than a thousand of plants. If in the Swedish varieties of winter-wheats hardiness is dependent on a large number of agents equal as to their importance (genes), the much more winter hardy varieties of this country should possess a still larger number of them. In order to combine in a single hybrid all the factors responsible for winter hardiness and to obtain transgressions, crosses should be carried out on a much wider scale than this was the case in Sweden; step-by-step hybridization is necessary in order to accumulate in a given variety all the factors of winter hardiness. Such has been in this country the general opinion as to the inheritance of winter hardiness in wheats. And it has been prevalent among breeders for no less than thirteen years. Hence their tendency to work with a maximum number of hybrids which they were practically in position to master.

Failures in breeding for winter hardiness are commonly due to an insufficient scope of the work. For lack of a theory to rely upon in assorting the pairs to be crossed, the breeders are left nothing else than to select the original varieties in a purely empirical way. And this is a reason more to enlarge the amount of the hybrid material involved. But a wide-scale-work hybridization necessarily implies a lack of attention in the evaluation of the hybrids obtained. Not infrequent are such cases where the breeder becomes able to estimate the winter hardiness of the variety bred only after he is ready with his work on this variety.

We have been the first to obtain according to a plan wheat hybrids transgressive as to winter hardiness, and with an exceptionally small number of F_2 hybrids, at that ([2]). In order to retrace the way which led us to a synthesis of winter hardy hybrids according to a plan formed beforehand, we deem it necessary to dwell upon the theory of the formation of winter hardiness in the ontogenesis of the plants.

According to investigations by I. I. Tumanov ([3], [4]), perennial wintering plants pass through two phases of hardening before they become winter hardy. The former proceeds in the light, late in autumn, at temperatures ranging between 6° and 0°. During this phase the plants accumulate considerable amounts of sugars. The second phase goes on at temperatures of about —3, —4°, when a considerable quantity of the plant's water is being turned into ice, *i. e.* when the plant's organism undergoes a well-pronounced dehydration. During this phase there is a

considerable increase in winter hardiness, provided a large amount of sugars has been accumulated during the first phase of hardening. Being of paramount importance for the knowledge of winter hardiness, Tumanov's doctrine of plant hardening accounts only for the last stages of the formation of frost resistance.

The senior author had a prolonged experience in his work with winter hardy wheats and Saratov winter hardy varieties of winter-wheats, in particular. In his opinion, the first step in inducing frost resistance and winter hardiness consists in the formation in the plants of a young anatomical and physiological structure of their most important organs and tissues which should survive winter, in order that the plant may continue to live. This first stage of development of winter hardiness received the name of the structural phase of resistance to the unfavourable conditions of hibernation.

It is only the young undifferentiated or poorly differentiated tissues, organs or whole plants that acquire a maximum winter hardiness after they have passed through the two subsequent phases of hardening (according to Tumanov). In all the wheats all over the world, strongly differentiated tissues and organs, and especially such as have already completed their growth, *i. e.* ageing and old ones, show a very poor adaptation to frost, and even to temperature decrease occurring late in autumn. They often perish before winter sets in. As an example may serve the well-known phenomenon of the first old leaves and culms which die off in very early plantations of winter crops by the end of autumn.

The structural phase of winter hardiness formation is more complicated and variable as compared with the two later phases. It is dependent on the climatic and agrotechnical conditions of growth and development of the wheats, including soil conditions. Because of the high variability of the plants during this phase, it offers ample possibilities for creating increased winter hardiness by agrotechnical means. On the other hand, a study of the agencies underlying variation makes it possible to remodel the hereditary basis of the organisms by means of breeding.

The rate of differentiation and of the subsequent ageing of the vegetable tissues and organs is dependent not only on the environment, but upon the cultural and varietal peculiarities as well. The latter produce a strong effect upon the rate of differentiation of the plants as a whole and upon their ageing. According to the theory advanced by T. D. Lyssenko, the ageing of a plant as a whole is dependent on the stages of its development: the shorter the developmental stages of a given plant—vernalization and light stage, the sooner does it achieve its individual development and the earlier ageing sets in.

The differentiation of tillering nodes, which plays a very important rôle in a safe hibernation of wheats, is also related with the developmental stages. As soon as the plant has passed the two developmental stages or by the end of the development of the light stage, there begins a rapid differentiation of the cones of growth and of rudimentary internodes, which means an irreversible ageing of the whole organisms of wheat plant. Prior to passing through the two developmental stages there is also a partial ageing of very early shoots, but, owing to tillering, rejuvenation takes place. Hence the tillering in grasses may be interpreted as an adaptation aimed to rejuvenate the organism and to create more winter hardy organs.

The lower the rate at which a given variety passes through its general phase development during autumn, the more it is likely to enjoy a favourable hardening stage under various environmental conditions. For this reason a higher winter hardiness will be displayed by such varieties of winter wheat as, *ceteris paribus*, will have a longer vernalization and light stage.

It is upon this reasoning that was based the principle of pair-assortment, advanced by us in 1936 in connexion with crosses for synthesis of winter hardy forms. The idea was that, when crossing two varieties more or less closely related as to hardiness, but widely different as to the length of their developmental stages, the hybrids derived may prove to exceed both parents in winter hardiness.

The experimental material contained in this communication is presented in the form of a cumulative list of the transgressive hybrids derived from three expe-

rimental sets. According to the characters we are interested in, the parental varieties of the hybrids fit within the following scheme. In all our spring wheats the vernalization stage is very short. With respect to the length of the light stage, they can be arranged into the following series: Prelude and 25183 have a very short stage; next follow 841, 48/02, 274, and at the long light stage end of this sequence are: 3483, 4952 and 321. The most winter hardy spring wheats, 3483, 4952 and 321, are not much below the less cold resistant winter wheat variety, *viz.* 3060/15. The length of the vernalization stage in winter wheats shows the following picture: 3060/15, 15 days; 534, 40 days; Cooperatorka, 45 days; Ukrainka, 50 days; *Hostianum* 237, 55 days; Br4, Br21 and *Lutescens* 329, 60—65 days. In the same order the winter wheats should be arranged according to the degree of their winter hardiness, the less cold resistant variety being 3060/15, and the hardiest Br4, Br21 and 329. With respect to the length of the light stage, the winter wheats form the following series in the ascending order: 3060/15, 534, Cooperatorka, Ukrainka, 237 and Br4, Br21, 329. The light stage of the last three varieties exceeds the corresponding stages in all spring components.

Number of Transgressive Lines According to Field and Laboratory Investigations of F_3 and F_4 in per cent to Number of F_2 Plants (data derived from three experimental sets carried out at Bezenchuk and Dnepropetrovsk)

Combination	Number of F_2 plants per set			I		II	III
				Field 1937—39		Laboratory 1937—39	Field 1938—39
				Transgression in resistance in %			
	I	II	III	to cold	to rotting	to cold	
321 × 534	—	224	—	—	—	1.3	—
3483 × 594	—	219	—	—	—	1.4	—
Prelude × Cooperatorka	217	—	—	0	0	—	—
841 × »	216	—	216	0	0	—	0
274 × »	195	—	217	0	0	—	0
321 × »	202	216	219	1.5	1.5	1.9	1.4
3483 × »	130	114	217	1.5	1.5	1.8	1.8
4952 × »	226	207	—	2.7	4.9	1.5	—
3060/15 × »	—	—	218	—	—	—	0
329 × »	—	—	220	—	—	—	0
Prelude × 329	218	—	—	0	0	—	—
25183 × Br4	230	203	—	0	0	0	—
841 × 329	221	232	—	0	0	0	—
48/02 × Br4	232	—	—	0	0	—	—
274 × 329	—	—	218	—	—	—	0
321 × Br21	215	228	—	0	0	0	—
329 × 534	—	—	207	—	—	—	0
Ukrainka × 329	—	—	215	—	—	—	0.0
3483 × Ukrainka	—	—	215	—	—	—	2.3
321 × Ukrainka	—	—	219	—	—	—	1.4

Out of the 20 combinations transgressive forms were obtained in seven combinations from a cross of three spring-wheat varieties with three winter-wheat varieties. In these seven combinations the light stage is longer in the spring varieties than in the winter components. The remaining 13 combinations gave not a single form transgressive for winter hardiness. Hybrids equalling in winter hardiness the most frost resistant parent, or closely approaching it were obtained almost in all combinations. According to our principle of pair selection, transgressive forms should be produced by crosses of certain Scandinavian winter-wheats with a number of steppe winter-wheats of this country and of the USA. We expect to obtain from

these combinations such wheat hybrids as will surpass in winter hardiness the most cold resistant hybrids all over the world. We started to work with them somewhat later, this is why the corresponding data could not be included in our list.

The above table which brings out the number of hybrid lines exceeding both parents in winter hardiness, permits of the following conclusions:

1. In the case of an adequate assortment of pairs in a cross there are frequent and constant transgressions for winter hardiness (cold resistance and resistance to rotting by moisture). On the average, the number of transgressions makes up 2 per cent to the total number of germinated F_2 obtained from seven combinations.

2. The frequency of transgressions among the hybrids obtained is thus many times that commonly adopted by geneticists and breeders during the last three decades. And this means that the theory of inheritance of winter hardiness advanced by Nilsson-Ehle should be discarded as being out of date; the huge scope of hybridization work which used to upset the breeders as being impracticable, appears to be unnecessary.

By increasing the winter hardiness of winter wheats the return of this crop may be made the double of what it is now. In order to obtain such varieties, there is needed a deep insight in the physiology of winter hardiness and its mode of inheritance, as well as the application of physiological evidence to the process of breeding.

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PALAEONTOLOGY

PATHOLOGICAL REFLEXES AND THE PROBLEM OF ANTHROPOGENESIS

By G. A. BONCH-OSMOLOVSKY

(Communicated by L. A. Orbeli, Member of the Academy, 26. I. 1944)

My part of the investigations carried out in collaboration with Dr. I. E. Prigonnikov is a direct continuation of the work of many years comprising the study of the hand and foot of the primitive fossil man found in the Crimea. To the I. P. Pavlov Institute of Physiology of the Academy of Sciences of the USSR belonged the comparison of the structural and physiological features of these organs of the Kiik-koba man with the morphological and reflex characters of hand and foot of modern man in their ontogeny and pathology.

The study of the foot was planned as the main part of the work, the investigation of the hand being, as it were, an addition to my published paper. Unexpectedly, this later part led to more rapid and interesting conclusions. We shall dwell here at greater length upon these, and only briefly summarize the observations on the foot.

Let us enumerate a few characteristic morphological features of the Kiik-koba foot: low longitudinal arch, great breadth of foot, stretching of toes. Big toe shortened, massive, the rest equalized in length. Little mobility of tarsus, except the third cuneiform, along with a great mobility of toes and ankle joint. Extensory setting of toes and metatarsals, and what is especially interesting, their markedly increased ability to physiological extension.

From the biological standpoint, these peculiarities are explained by the balancing necessity of the ill balanced body of Neanderthal man. It is a consequence of the imperfection of the erect position, the latter being still in formation, and an adaptation to semi-mountainous eroded landscape, in which the remains of this species of man are usually found.

From the morphological standpoint, the full similarity in all characters of the Kiik-koba foot to that of the foetus and newborn babies is striking. The stretching of toes and the physiological extension correspond precisely to the position of child's foot under the Babinsky reflex. Hence follows a necessity to compare the Neanderthal foot with the Babinsky reflex in pathology.

The difficulty lies in the insufficiency of the characteristic of the Babinsky reflex in the literature. Habitually, it is characterized as an extension of the big toe. In this sense it is hardly applicable to the Kiik-koba foot in which the extension of the big toe is just the least pronounced, and to children, in whose feet, as a rule, after my former observations, all the toes extend forming a fan. The fan symptom is insufficiently characterized in its relation to the classical Babinsky reflex.

There exists also a difference of opinion as to the interpretation of the phyletic meaning of this reflex. Astvatsaturov(1), and it does him credit, regards the Babinsky reflex as a vestige of the early grasping foot. Borovsky (2) thinks it to be a

remnant of the peculiar supporting function of the Neanderthal man. Besides, the relations of still a number of pathological reflexes to the structure of the foot of the primitive man are completely unknown.

All these problems arose before us, and were to be solved at further exploration.

The brief results of this preliminary work are as follows: we analysed carefully and tried to fix all the characters of the Babinsky reflex. An extension of the big toe alone, without a fan, is extremely rare, usually there takes place extension of the first and second toe, of the first to fourth toe, or of all toes, with a fan. Often occurs a fan without an extension. To sum up, we return in the definition of the Babinsky reflex to its author who spoke of the «phénomène des orteils», and not «du gros orteil». The chief result of our observations is the full conformity of the Babinsky reflex in pathology with the characters of the Kiik-koba foot, and with the Babinsky reflex in children. This conformity is observed in some details, too: mobility of the third cuneiform, *viz.* of the third toe, or, in the fan condition, maximum divergence between the second and third, or third and fourth toe.

Only a slight divergence of the big toe is observed, contrary to the habitual conception of the Babinsky reflex, as of a vestige of the grasping foot.

Let us turn to the evidence presented by the hand. The latest investigations of fossil man brought many new conceptions into the problem of the phylogeny of the hand.

Not long ago this problem seemed to be rather simple: the grasping-toiling hand of man arose by way of slight modifications from the grasping-climbing forelimb of ape; it is therefore a very old phyletic structure.

The finding of a rather complete set of bones of the hand of primitive Neanderthal man in the cave of Kiik-koba in Crimea made us put the problem of the structure of this organ in the whole Neanderthal group of man in a quite different way.

Quite unexpectedly the Kiik-koba hand, besides a number of other features, proved to lack the opposability of the thumb. The sellar joint is replaced in the Kiik-koba hand by a simple cylinder, and the major multangular is inclined under a minor angle to the plane of carpal bones. This indicates that the thumb was to a greater extent set in the palmar plane than in modern man.

I cannot dwell more in detail upon these problems; they are sufficiently dealt with in my monograph on the hand of fossil man. I will only point out that the most plausible explanation of all these peculiarities in the structure of the hand of our ancestor, primitive man, consists in that the still more remote ancestor, at the stage of higher anthropoid ape, was not adapted to arboreal life, *i. e.* he was ground dweller, and his forelimbs still fulfilled to some extent the functions of support.

The smaller opposability and a number of other features in the Kiik-koba hand are just the remnants of this supporting function in the process of formation of the grasping-toiling hand of man.

However, if the opposability (and we shall now consider only this feature) were such a recent phyletic formation, it would seem natural that its falling out ought to manifest itself to some extent in the ontogeny and pathology of modern man taken from evolutionary standpoint.

By the time when I was finishing my monograph, I had at my command but a few facts:

1. Observations of the American biologist Shultz on the absence of opposability in human foetus. In a 8—9-week-old embryo the thumb lies in the palmar plane.

2. Observations of Dr. Kryshova, made at my request, upon the rôle of the thumb in the grasping act of new-born babies. She arrived at the conclusion that in them «the thumb does not practically take part in grasping, this inaction being especially manifest when asleep».

3. I was aware of the data available in neuro-pathological literature as to the elimination of the opposability of the thumb after injury of the pyramid paths. However, as there exists no evolutionary interpretation of this elimination, which

is quite natural from the habitual point of view on the phylogeny of the hand, I have not included this topic into my book, thinking that all these problems of elimination of the opposability in ontogeny and pathology need further investigation.

In the first instance there arose the necessity of a more precise analysis of the absence of opposability in younger sucklings, and of a comparison with its elimination following to injuries of the central nervous system.

In the neuro-pathological literature many methods of determination of the opposability are described. However, all these methods seemed to me scarcely adequate, for (1), all adult and healthy persons are equally capable to answer them; thus, they do not reveal any variations of opposability; yet these latter ought to be present, if this feature were a phyletically recent acquisition; (2) these methods require a voluntary act, and are not applicable to sucklings. As a result of observations on sucklings, I concluded that the best expression of opposability, meeting all demands, is the «fist» test varying in adults, and which we can call forth in newborn babies.

Having proposed my method of determination of opposability, I was far from an idea of its clinical application. When I. E. Prigonnikov, my collaborator in this work, observed it, we together improved the application of this test which received the name of «Bonch-Osmolovsky test», and started systematic observations on healthy and ill persons.

Let us dwell upon the methods of application of the test. The person under test flexes the second to fifth fingers, tightly, but without strain pressing them to the palm, and putting the thumb on their knuckles. Among 100 tested healthy adults 50 reach by the tip of the thumb the first knuckle of the 4th finger. 24 per cent have a still greater opposability: the thumb reaches the first knuckle of the 5th finger or the interspace between the 4th and 5th finger. 26 per cent, mostly in the case of a muscular type, possess a limited opposability; the thumb can reach but the 2nd phalanx of the 4th finger, or in a few cases, the 1st knuckle of the 3rd. Irrespective of the degree, the opposability in healthy persons is always symmetrical in both hands. In younger babies the opposability is also symmetrical, but limited: the thumb can cover the 3rd finger, sometimes only the 2nd, its 1st or 2nd phalanx. Out of 74 persons with different injuries of the central nervous system, in 50 a marked asymmetry of opposability was observed with a sharply pronounced limitation on the injured side: in most cases it did not reach beyond the 2nd or 1st phalanx of the 3rd finger, occasionally only to the 2nd phalanx of the 2nd finger. The normal hands of this latter category gave the maximum of cases, like in healthy persons, on the 1st phalanx of the 4th finger, with a marked shifting of the curve towards smaller opposability. In 24 cases (of slight phenomena in conducting paths), though the symmetry was preserved, there was still a certain decrease of opposability in both hands.

In some fully checked cases, this test allowed to state some injuries of the central nervous system, which had occurred a few years ago (contusion, head-trauma) and at present did not manifest themselves in any other phenomena.

To sum up, the facts obtained by means of the test described, *viz.* reduction or absence of opposability after injuries of the central nervous system, as well as in younger babies, confirm the view as to the early supporting function of the hand which survived in the structure of the Kiik-koba hand being still manifest in the pathology and in the ontogenesis of modern man.

By the time when I was finishing my book on the hand of Kiik-koba fossil man, I had at my disposal but a few facts on the extension of the hand as a sign of a surviving early supporting function.

These facts are:

1. Absence of the palmar curving of phalanges in the Kiik-koba hand.

2. Observations by Hrdlička to the effect that infants of all, even most primitive peoples, from the earliest «on-all-four» age, crawl, like all monkeys, resting upon the open palm. It would seem natural to expect considering the late arboreal past of man, that our children progress, like the anthropoids, upon the knuckles.

3. Observations by Kryshova that the hands of younger babies are usually in extended condition during sleep.

4. Observations on a live 6-month-old foetus which I happened to make: his hands were continuously in extended condition.

At that time I was far from believing that the evolutionary significance of the extension will be confirmed by pathological evidence, too, however, the phenomenon of the thalamic hand, i. e. of one involuntarily keeping the fingers stretched, as well as the «stretching symptom» recently established by myself, consisting in a hypertension and stretching of the fingers upon irritation of the palm in patients with severe injuries of the central nervous system, go to support this view.

Thus, pathology also furnishes data on the extension phenomena, which confirm the idea as to the early supporting function of the hand*.

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* I wish also to mention here the personal information by Prof. Pakhomov about a patient suffering from epilepsy who lapsed after fits into sleep; directly upon awakening, her hands invariably assumed the attitude of extension.

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EXPERIMENTAL EMBRYOLOGY

EXPERIMENTS ON TRANSPLANTATION AND REMOVAL OF ORGAN RUDIMENTS IN EMBRYOS OF *ACIPENSER STELLATUS* IN EARLY DEVELOPMENT STAGES

By A. GINSBURG and T. DETTLAFF

(Communicated by I. I. Schmalhausen, Member of the Academy, 22. IV. 1944)

D. P. Filatov (1) has been the first to apply experiment to the study of the embryology of *Acipenseridae* (*Acipenser stellatus*, *A. güldestädtii*); and so far as we know, his experiments made on embryos of those fishes have not been repeated by anybody else. They concerned chiefly the relation between the development of the ear capsule and the ear vesicle. The operations on the neurula proved a failure, for the embryos perished soon.

Nevertheless, these experiments gave to the development mechanics a novel and interesting object.

While working in summer 1940 at the Nikolsky fish-breeding station on the Volga on embryos of *Acipenser stellatus* we succeeded in obtaining some preliminary data by experimenting on the early stages of their development (gastrula and neurula).

Taking into account the peculiar place occupied by the sturgeons among the rest of fish [Sewertzoff (2) showed that they are the most primitive group of *Holostei* most closely approaching the *Selachii*], experimental embryological work carried on with the *Acipenseridae* is likely to contribute largely to the knowledge of embryogenesis in its evolutionary aspect. They are of special interest moreover as, unlike bony fish, they possess holoblastic eggs. Their early development stages do therefore greatly resemble corresponding stages in the development of amphibiae, owing to which they may readily be compared with the latter. And this is of particular value, for the development of amphibiae has been studied in more detail than in any other group of animals.

The following experimental sets were carried out by the authors: 1) removal and grafting of the dorsal lip of the blastopore, 2) removal of the presumptive eye rudiment and 3) removal of material of the hind brain.

Embryos of *Acipenser stellatus* were obtained by us at the Station for Artificial *Acipenser* Fish Propagation by the method of Gerbilsky. The experiments were carried on in June and early in July; it should be noted, however, that fertilized eggs could be obtained at the Nikolsky station since the first half of May and until middle July, i. e. during two months or two months and a half. The possibility to operate within such ample a period is of great value.

In early stages the embryos of *Acipenser stellatus* are somewhat larger than those of the axolotls (about 3 mm across). Unlike amphibians, they have their vegetative pole pigmented. It is a matter for regret that the development of this sturgeon has not been described in detail; monographic descriptions of a closely related form, *viz. Acipenser ruthenus*, are however available in literature (3, 4). The development proceeds at a rather high rate: gastrulation sets in after some

14—16 hours upon fertilization at a temperature of 19—20° C; neurulation takes place by the second day. The development of the embryos can be inhibited by keeping them at lower temperatures; a temperature reduction to 10—11° C, however, is sufficient to bring about disturbances in the normal development in a considerable per cent of cases.

A rise beyond 25° C may also be harmful. The best results have been secured by keeping the operated embryos at 17—20° C.

Previous to operation, the embryos in their shells were put for 1—2 seconds into 70° alcohol; then the alcohol was washed off by a sterilized physiological solution.

After this the embryos were freed of their shells with the aid of finely sharpened watch-pincers. In some of the cases the embryos were not taken out of their inner shells, and we contented ourselves with making a small window through which the operation was made. If the whole shell was taken off, the embryos were placed into dishes whose bottom had been covered with a thin layer of agar-agar. A habitual set of instruments served for the operations: a finely sharpened iridectomy knife or a glass needle, and a hair-loop. An important difficulty which we failed to surmount to full extent consisted in the choice of a suitable physiological solution. By varying the concentration of the solution, we succeeded, however, in obtaining several normally developed embryos; some of them could be brought to a stage which the control larvae used to attain 24 hours upon hatching (length 7.5—9 mm). The embryos were fixed with Bouin's solution, stained totally with boric carmine and subjected in sections to after-staining with indigo-carmine or after Mallory.

1. Removal and Grafting of the Dorsal Lip of the Blastopore. The experiment was carried out in the same way as it is usually done in amphibians. After preliminary vital staining with Nile-blue sulphate, out of an embryo in the stage of the middle gastrula was cut the central portion of the blastopore lip, including the part already invaginated and a small adjoining strip (in amphibians a similar graft contains material of the head-gut and the central portion of the chordo-mesodermal rudiment). The material removed was grafted to another, unstained embryo superficially, in the region of the prospective belly epidermis. The hosts were taken in the stages of early and middle gastrula. In the case of *in vivo* observations, the stained grafts could be seen fully to invaginate under the ectoderm, in the same way as this proceeds in amphibians.

Four embryos have been fixed at the stage of the tail bud. When dissected, in two cases a well-shaped neural tube could be seen above the graft, while in the third case the inner layer of the ectoderm was simply thickened, and in the fourth case there were no traces of induction whatever. By the time of fixation a section of the gut has already been differentiated in the graft. The chordo-mesoderm was not segmented and represented a compact cellular mass. Neither the graft, nor the notochord of the host showed the typical differentiation of their chordal cells.

The results obtained make us believe that in *Acipenser stellatus* it is the dorsal lip of the blastopore which, like in *Cyclostomata* ([5]), bony fish ([6,7]) and amphibians, induces the nervous system.

Great interest should be attached to one of the embryo-donors which was brought up to a stage corresponding to that of the tail bud in the control. The edges of the wound at the place of the removed central part of the dorsal lip of the blastopore were found to join soon, and the gastrulation seemed to proceed quite normally.

Further on, however, when the control embryos have reached the neurula stage and that of the tail bud, the donor continued to maintain its spherical shape, and formed no neural plate. A total lack of a nervous system could be recorded on sections, as well. Besides the nervous system, there were no axial organs, notochord and dorsal segments either. There was nothing but an unsegmented mass of mesoderm which seemed to correspond to the lateral plates.

This case which remained unfortunately unique, goes to confirm the existence of a relation between the development of the nervous system and the axial organs; at the same time it makes one assume that in *A. stellatus* the material of the chordomesoderm inducing the neural plate is confined to a smaller area than in amphibians.

In the later operations similar to that here described lead invariably to a regulation of the embryo. In bony fish *(Fundulus)*, on the contrary, a removal of a sector of 45° from the blastodisc of an embryo in the stage of the middle gastrula is sufficient to bring about the absence of the chord, or even a total lack of all the axial structures ([8], p. 43). From this point of view a further investigation of the sturgeons is of particular interest, for they may be expected to show a localization of their organ rudiments more closely approaching that in bony fish, in spite of the holoblastic type of segmentation, in which they approach the amphibians.

2. Removal of Presumptive Eye. At the stage of early neurula the anterior right section of the neural plate was cut out together with the medullary fold up to the underlaying chordo-mesoderm in the same way as it had been practised in amphibians. Unfortunately, a single embryo could be fixed in this set, which was safely grown up to the stage of elongated tail bud. In sections the left eye was found in the stage of the eye vesicle, in no contact with the epithelium, while the right eye was entirely missing.

Thus, in *A. stellatus* the material of the eye seems to be determined as early as at the stage of the early neueula.

3. Removal of Material of Hind Brain. The experiments consisted in removing the right half of the presumptive hind brain together with a certain surplus of the material of the medullary plate before and behind it, and a small portion of the left half of the hind brain. The experiment comprised two main runs: the removal of material of the medullary plate together with the adjacent part of the medullary fold, and without the latter. In either case, in some of the embryos the medullary material was cut out together with the underlaying chordomesoderm.

But as this detail did not tell upon the results of the experiments, we shall not dwell upon it in this place.

When practised in the stage of early or middle neurula, the removal of medullary material without medullary fold resulted in all cases (a total of four embryos fixed) in a regulation of the brain; two ear vesicles were formed, but on the operated side they were smaller than on the control side.

When the medullary material was removed together with the medullary fold at the stage of the middle neurula (six embryos fixed), no regulation of brain took place in any of the cases, and ear vesicles failed to form on the operated side. Out of the embryos operated in the stage of late neurula three were fixed. In two cases the wound did not close, and the entoderm protruded in the shape of a dome; all these embryos showed no brain regulation, and there were no ear vesicles on the right side. In the third embryo a partial regulation of brain took place and a small ear vesicle developed, correspondingly.

An identical result has been obtained when operating at a later stage (that of closure of neural tube, two embryos fixed).

Thus, ear vesicles are not formed on the operated side, save for the cases where as a result of regulatory processes there is development of the right half of the hind brain, be it a deficient one; and the less expressed the regulation of the brain, the smaller is the vesicle formed on the right side. This is evidence of the fact that in *A. stellatus*, like in amphibians ([9-11]), the hind brain rudiment produces a determining action upon the neighbouring ectoderm, calling forth the development of ear vesicles.

The absence of ear vesicles in the case of the removal of a part of the medullary plate together with the neural fold in the stage of the middle neurula should evidently be taken to mean that in this stage the ectoderm of the ear region has not yet been determined. The cut was practised along the external edge of the fold. We believe that the material of the ear rudiment remains in its place; in amphi-

bians it is located outside the external edge of the fold, and the similarity in the arrangement of the rudiments of the eye and the hind brain in *A. stellatus* and in amphibians makes us expect that the rudiments of the labyrinth occupy in embryos of these animals a similar position. It is, of course, necessary to determine the precise position of the ear vesicle material in the various stages of development of *A. stellatus*.

Unfortunately, the attempts to do it by the method of local vital staining could not be brought to a successful end.

At the stage of the middle neurula the material of the hind brain is already determined, for in the case of the removal of a half of the rudiment, the corresponding half of the hind brain is also lacking. Curiously enough, if the same part of the medullary plate is removed at a later stage, regulation is still possible.

In conclusion, it should be said that *Acipenseridae* offer an extremely convenient material for experimental embryological investigations.

The results obtained give us ground to believe that in the embryonic development of *A. stellatus* we are dealing largely with the same phenomena as in the development of the rest of vertebrates, *viz.*: 1) the inducing action of the one part of the embryo upon another [the chordo-mesodermal rudiment induces the nervous system, the rudiment of the hind brain induces the ear vesicles, the latter, according to data by Filatov ([1]), attracts the capsule-forming mesenchyme]; 2) the determination of material revealed in the development stages investigated (dynamical determination of the dorsal lip of the blastopore, material determination of the chordo-mesodermal rudiment in the middle gastrula, of the eye in the stage of the early, and of the hind brain, in that of the middle neurula); 3) regulatory changes in the case of disturbances of typical development (regulation of the hind brain upon removal of a half of its rudiment).

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EXPERIMENTAL MORPHOLOGY

A COMPARATIVE STUDY OF LENS-FORMING PROPERTIES OF BODY EPITHELIUM AT VARIOUS DEVELOPMENT STAGES IN *BOMBINA BOMBINA* AND *AMBLYSTOMA MEXICANUM*

By A. P. SHEINA

(Communicated by I. I. Schmalhausen, Member of the Academy, 12. XII. 1943)

The experiments here described were carried out with the aim to compare the lens-forming properties of the body epithelium in *Bombina bombina* with those in *Amblystoma mexicanum* in stages preceding that of typical lens-formation. Filatov [1] proved the possibility of a lens induction by means of grafting the eye-cup of an embryo from whose development the presumptive chordo-mesoderm had been eliminated in order to prevent the development of a nervous system. Along with the main conclusion derived, the author has also found that in these experiments the lens had been formed in an earlier stage than this usually takes place in the case of typical development, *viz.* at an age corresponding to the early tail bud of a normal embryo. Hence it follows that at a period preceding the formation of a typical lens, the epithelium of the trunk is already able to respond to the morphogenetic action of the cup by forming a lens.

The question as to whether body epithelium is endowed with a lens-forming ability at still earlier developmental stages, was investigated by the present author on *Rana temporaria*, *R. esculenta* and *R. arvalis*[2]. In her experiments with the gastrula she succeeded in showing that the prospective body epithelium of the three species is endowed with lens-forming properties which in this stage of development were found to be identical in all of them.

When grafted under the ectoderm of the late gastrula of *R. temporaria*, *R. esculenta* or *R. arvalis*, the eye rudiment invariably induced the same reaction of the epithelium, irrespective of the species to which the latter belonged: a lens was formed in 100 per cent of the cases where the eye-cup was correctly oriented with respect to the epithelium. In *R. arvalis* and *R. esculenta* the lens-forming reaction of the epithelium was found to be more intense as compared with the lens-forming reaction of the body epithelium in the stage of typical lens-formation. In the stage of gastrula *R. temporaria*, *R. esculenta* and *R. arvalis* proved thus much alike with respect to lens-formation; in the stages following the gastrula, however, the three species displayed differences which are dependent on the age variations of the epithelium. A comparative study of the process of lens-formation carried out on different species and in different stages, besides, made it possible to reveal the cause responsible for those differences. It was found possible to bring out that in different species the lens-forming ability becomes less intense not at the same age, and that this process goes on at a different rate. Owing to this, the species investigated show a different reaction of body epithelium in stages following that of the gastrula.

In the stage following soon after the closure of neural folds the epithelium of

R. temporaria (3) formed lenses in all cases where the grafted eye rudiment had developed into a good and correctly oriented cup.

In my experiments with *R. esculenta* and *R. arvalis*, which were carried on with animals at the same stage of development, the grafts being also in a similar state, I happened to observe along with cases of successful lens-formation, such cases were there was no lens-formation at all, or else there was formation of a deficient lens. The conclusions formulated above have been derived by the author from the study of the lens-forming properties of the trunk epithelium in *Rana temporaria*, *R. esculenta* and *R. arvalis* in the stages preceding the typical lens-formation. Manuilova (4) investigated age variation of the lens-forming ability of the trunk epithelium in *R. temporaria* and *R. esculenta* during the stage corresponding to the period of the development of a typical lens and following typical lens-formation. This writer arrived at a conclusion that the abatement of the lens-forming properties of the body epithelium proceeds in *R. esculenta* and *R. temporaria* at a different rate.

The body epithelium of *R. temporaria* maintains its lens-forming ability much longer than that of *R. esculenta*; the body epithelium of tadpoles of *R. temporaria* in the stage of hatching is still endowed with a lens-forming ability: out of the sixteen embryos with a well-developed grafted eye-cup, four displayed a lens rudiment. In *R. esculenta* the epithelium showed a similar reaction in a much earlier stage, *viz.* in the stage of the late tail bud.

In order to check up the above-said on an ampler material I undertook the present experiments which consisted in a comparative study of the lens-forming capacity of the trunk epithelium in *Bombina bombina* and *Amblystoma mexicanum* in two developmental stages, that of the late gastrula, and that following the closure of neural folds. The objects of the investigation were not taken at random. In the experiments made during the stage of the tail bud the formation of a lens from body epithelium is observed but on rare occasions both in *Bombina bombina* (5) and *Amblystoma mexicanum* (6). If early epithelium of the species investigated were found to possess a lens-forming ability increased as compared to those in the stage of the closure of neural folds, as it has been found by the author for *R. esculenta* and *R. arvalis*, it would then be possible to observe a reduction of the lens-forming capacity within the stages concerned. For my experiments I made use of embryos of *B. bombina* and *A. mexicanum* at the stages of late gastrula and at the stage following the closure of the neural folds. The embryos were fixed with Bouin's solution every 1.5—4 days in *B. bombina*, and every 3—9 days in *A. mexicanum*. All the embryos were totally stained with boric carmine. The sections were made 7—9 microns thick.

1 s t s e t. The main experiments aimed at investigating the lens-forming properties of the gastrula ectoderm, the prospective body epithelium. The operations consisted in grafting the eye rudiment from a stage following the closure of neural folds into a pocket previously prepared on the belly or flank of a late gastrula. In order to be able to determine with greater precision the early stage when the epithelium begins to respond to the morphogenetic action of the graft, the age of the lens developed from body epithelium in each separate case was compared to the age of a lens of a normal eye, both of the host and the donor. Along with the operated gastrula, control donor was left for each case. This set comprises 75 operations made on *Bombina bombina*, 50 of which were investigated, while the rest did not survive a date when fixation could be done. Out of the 50 embryos examined only 20 had their eye rudiments developed into a cup; only in 14 embryos was there development of lenses, which makes up 70 per cent. In 6 embryos, in spite of a rather correct orientation of the eye-cup, no changes of epithelium could be observed. In 23 embryos the eye rudiment failed to develop into a cup; in 4, the eye-cup showed an irregular orientation; in 3 embryos, the cavity of the cup was found to contain mesenchymatous cells which evidently prevented the necessary contact between the cup and the epithelium. The developed lenses are at different stages of development; from a mere thickening of the epithelium and to the differentiation into epithelial cells and cells of fibrous mass.

50 operations were made on *Amblystoma mexicanum*, 35 cases were investigated. In 18 embryos the eye rudiment was found to have developed into a cup; in 15 there was formation of lens rudiments (83.3 per cent); 3 embryos showed no changes of epithelium whatever; in 12, the eye rudiment failed to develop into a cup; in 5, there was an incorrect orientation of the graft. It should be noted here that the age of the transplanted eye and of the lens which developed under its influence does mostly lag behind the age of the eye and the lens on the unoperated side (2nd control), both in *Bombina bombina* and *Amblystoma mexicanum*. Such cases, however, where the eye of the host (1st control) has no lens still, while the lens of the same embryo has already developed under the morphogenetic influence

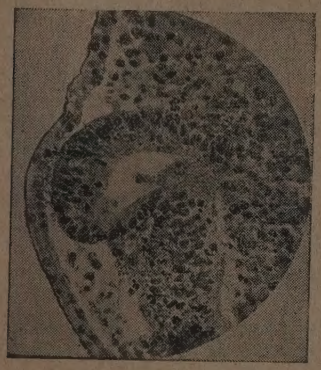

Fig. 1. Cross-section through the head of the recipient (1st control). Eye vesicles adhere to the neural layer of epithelium; no lens laid down

Fig. 2. Cross-section through the ventral region of the same embryo. The grafted eye rudiment developed into a well-shaped and sufficiently concave cup; its external layer is not pigmented yet. The lens represents a vesicle which dit not yet separate from the neural layer of epithelium; its cavity contains accumulation of pigment. The lens developed is somewhat smaller in size than the lens of a normal eye of the donor

of the graft, should be interpreted to mean that under the given experimental conditions the morphogenetic effect and the lens-forming reaction set in much earlier than this takes place in the case of a typical development. The figures illustrate a case of *Bombina bombina* No. 103, operated upon on June 17, fixed on June 19 (Figs. 1, 2, 3).

2nd set. The experiments consisted in testing the lens-forming capacity of the body epithelium in the stage of closed neural folds; an eye rudiment of the same stage was grafted on to the flank in a pocket prepared beforehand.

Bombina bombina was operated upon in 75 cases, 62 of them could be examined. In 31 cases the eye rudiment developed into a cup, lenses developed in 17 embryos, which makes up 54.8 per cent of cases. In 14 embryos there was no development of lenses from body epithelium; in 17 cases the eye rudiment failed to develop into a cup; in 11 embryos the cup cavities were filled with mesenchymatous cells; in 3 cases there was an incorrect orientation of the eye-cup.

The results of these experiments are somewhat at variance with the data secured by Chanturishvili (5) who investigated the lens-forming capacity of the body epithelium of *B. bombina* in the stage following soon after the closure of the neural folds and in the stage of the early tail bud.

Out of the two sets of grafts of the eye rudiment under the body epithelium and of body epithelium on to the eye (a total of 34 operations) Chanturishvili was able to observe development of the lens in 2 embryos only. It is a matter for regret that this writer does not mention in how many cases of the 34 operated upon the state of the graft was promising with respect to lens development. According to my

information, the eye rudiment of *Bombina bombina* when grafted under the trunk epithelium fails to develop into a cup in 25 per cent of the cases.

Most of the embryos of *Amblystoma mexicanum* of the second set did not survive operation. 9 embryos could be fixed; only in two of them the eye rudiments developed into cups; in one there was development of a lens; in another the lens failed to develop. But as the number of cases is obviously insufficient, the data obtained in the first experimental set will be compared here with those secured by Manuilova and Kislov from their experiments on *Amblystoma mexicanum* ([6]). While studying the lens-forming properties of the trunk epithelium in the stage of the tail bud, these writers observed the development of lenses only in 7 embryos out of the 24 cases with a rather successful development of the eye-cup, which makes up 29.1 per cent.

Fig. 3. Cross-section through the donor's eye (2nd control); the cup of the normal eye is sufficiently concave, its external layer is pigmented; the lens has the form of a vesicle which still preserves its contact with the epithelium

A comparison of the results of the first set with those of the second permits of the following conclusions:

1) In experiments involving the gastrula, the prospective body-epithelium of *Bombina bombina* and *Amblystoma mexicanum* is found to be endowed with lens-forming properties. An eye rudiment grafted under the ectoderm of the late gastrula induces in the epithelium the formation of a lens much earlier than this takes place in the case of a typical development, and at a higher frequency than in the experiments made in the stage of the closure of neural folds. In *B. bombina* lenses developed in 70 per cent of cases, in *A. mexicanum*, in 83.3 per cent.

2) The results of the 2nd set of experiments make it evident that in *A. mexicanum* the reduction of the lens-forming properties proceeds within a shorter period of time than in *B. bombina*; in the former lens development could be observed in 29.1 per cent of cases ([6]), in the latter, in 55 per cent.

The results of the experiments here described go thus clearly to confirm the data on age variations of the lens-forming properties of the trunk epithelium in *Rana temporaria*, *R. esculenta* and *R. arvalis*, largely secured in the course of an earlier comparative investigation. The only difference consists in that experiments made at the stage of gastrula gave a smaller number of positive results.

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